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EFFECTIVE USE OF ERTS MULTISENSOR DATA IN THE NORTHERN GREAT PLAINS

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EFFECTIVE USE OF ERTS MULTISENSOR DATA IN THE NORTHERN GREAT PLAINS

JULY, 1974

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16. Abstract

ERTS imagery was used as a tool in the identification and refinement of soil assoication areas; to classify land use patterns between crop and fallow fields; to identify corn, soybeans and oats; and to identify broad generalized range ecosystems. Various data handling techniques were developed and applied to accomplish these tasks. A map outlining soil associations and relative land values was completed on a base mosaic of ERTS imagery and included as appendix B to this report.

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PREFACE

(a) Objective: The overall objective of the interdisciplinary research project reported upon in this document was to determine the effective use of ERTS-1 multisensor data in the assessment and management of resources in the Northern Great Plains area of the United States.

(b) Scope of Work: The research project was conducted in five related areas; namely, Rangeland, Cropland, Land Systems, Soil Influences in Crop Identification and Data Handling. While these research areas are discussed separately in the report, the investigators maintained close liaison and held frequent meetings to exchange information and progress reports. Specific study-area sites were selected for each research category and multi-level data were collected in each, including ground truth, low level aircraft data and data from NASA aircraft at high altitude. These data were compared, both optically and with machine analysis techniques, to sequential data obtained from the ERTS-1 satellite. The goal of these efforts was to develop the capability for mapping kinds of rangeland and assessing seasonal or long-term changes; to assess the usefulness of ERTS-1 data for crop resource inventory; to recognize soil association boundaries on ERTS-1 images and mosaics and to publish soil association maps on that imagery; to account for individual soil differences on ERTS-1 imagery so that more precision can be gained in crop identification; and to develop data handling techniques to enhance research in each of the study categories undertaken.

(c) Conclusions: It was concluded that ERTS-1 imagery is useful for refining boundaries of major soil and vegetation types and for distinguishing cropland from rangeland, but greater resolution with more and narrower bands appears to be necessary to provide information for use in range management; that May and late August ERTS-1 imagery is most useful for crop identification, however, development of less expensive machine data handling techniques is necessary for an operational crop identification system; that ERTS data can be effectively used to identify soil associations and can also be used as a base map upon which to publish soils information;

and that differences in radiance values of different crops can, in part, be accounted for by soil differences.

(d) Summary of Recommendations: Extensive recommendations for each study area are included in the report. Briefly, these recommendations are broadly summarized as follows: Rangeland - to evaluate the vast amount of remote sensing data which can be collected by airborne sensors, it is necessary to develop improved techniques and procedures to collect ground truth information rapidly and to process it as an analysis tool for interpretation of the airborne imagery. Cropland - additional research is needed to develop methods that account for soil and stress variables in crop spectral reflectances. Land Systems - the temporal, multisensor, near-orthographic imagery of the ERTS system should continue to be analyzed as a valuable tool to use in the study of soils and the soil-plant relationships. Soil Influences in Crop Identification - controlled experiments and major soil associations should be conducted utilizing ERTS imagery, and involving several stages of growth over a period of time extending from May through September. Vegetation prediction and vegetation yield modeling appears to be feasable following these controlled experiments.

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1. INTRODUCTION

1.1 BACKGROUND: Interest in the need to more effectively monitor and utilize available natural resources has grown steadily over the past few years. Availability of repetitive imagery from space platforms has obviously added a new dimension to developing methods for resource monitoring as well as for many other purposes. The time-dependent parameters which influence resource monitoring of crops and rangeland also furnish important clues with which to identify land systems and consequently to develop relative land values. Sequential imagery from the Earth Resources Technology Satellite (ERTS) lends itself well to supplying this temporal view. Also, because of the large areas of cropland and rangeland in the Northern Great Plains region, ERTS imagery provides the only currently available source of data which may be utilized for development of resource monitoring techniques on an economically feasible basis. For these reasons, it was proposed that the Northern Great Plains area, which provides a large and relatively homogeneous geographical region, be used as one of the research areas to confirm the applicability of ERTS imagery to assessing earth resources. Range, crop and soil characteristics which are unique to the Northern Great Plains area are well defined and have been the subject of conventional studies by the Agricultural Experiment Stations and federal agencies for many years. Data and experience produced by these continuing studies provide an excellent foundation on which to build the new techniques for an operational system using satellite sensor data in the assessment and management of natural resources. The vast amount of data available from space imagery also necessitates the development of new data handling methods. Concentration on this important phase of research was also included in this project.

1.2 GENERAL OBJECTIVES:

1.2.1 To develop capabilities for an operational system using satellite sensor data in the assessment and management of resources in the Northern Great Plains.

1.2.2 To investigate procedures for predicting land, soil and crop patterns from ERTS data.

1.2.3 To study changes in quantity, quality and distribution of resources in the Northern Great Plains Multidisciplinary test site.

1.2.4 To evaluate a man-machine interactive data processing system with ERTS data.

1.2.5 To produce maps of areas demonstrating the utility of ERTS imagery for delineating these resources.

1.3 GENERAL APPROACH: Four major areas of study were conducted simultaneously and each will be reported upon separately in this report. These studies were focused upon rangeland, cropland, land systems and data analyses. A study to account for soil influences in crop identification was also conducted during an extension of the original ERTS contract. Each study area reported upon is complete in itself, that is, conduct of the study from organization to conclusions is reported upon before moving on to the next area. While the studies are treated herein as separate and distinct efforts, it should be noted that there was much cooperation and exchange of information among the co-investigators throughout the entire research project. In fact, research done on the soil normalization study was the joint effort of two of the investigators who had conducted separate studies on cropland and land systems. Meetings of co-investigators were scheduled frequently to coordinate the work in progress and also to exchange ideas and report the results of work in progress. These meetings served an important educational purpose for the staff as well as providing the necessary coordination guidance.

1.4 STUDY AREA APPROACH: The basic approach under each application study area relative to utilizing the Great Plains concept to obtain and coordinate data was similar to the others. In each, a set of specific sites was established. In all cases, these sites are existing field stations of the state Agricultural Experiment Station or existing remote sensing study areas. This approach permitted use of the extensive background information available for the site, highly experienced field personnel, existing instrumentation at certain of the sites and a wide variety of study sites without need to establish new test areas. The following study-area approach was used.

1.4.1 Sites for collecting detailed ground truth were selected to be representative of typical soil and plant resources in the area. Initial aircraft coverage of each site was obtained as soon as possible to aid in planning and resource inventory.

1.4.2 At each experimental area, plots or fields were selected large enough in size to be identifiable from space imagery. Measurements necessary for relating ground truth to ERTS imagery were made at each site. Soil, vegetative and climatological data were the principal parameters involved in ground truth measurements. Ground truth measurements made at the sites included the unique factors identified by the members of each discipline team. All measurements made at the site representing a single discipline, for example range, were identical insofar as possible. This insured comparability of measurements and results.

1.4.3 Pattern recognition procedures were tested for satellite and aircraft imagery and the results were verified through ground truth missions.

1.4.4 With the facilities at The Remote Sensing Institute, satellite imagery was analyzed. Data handling and interpretation procedures were tested and modified as necessary. New techniques were developed where present procedures were not satisfactory.

1.4.5 NASA aircraft and SDSU remote sensing aircraft were used for detailed studies of sensors, targets, instrumentation, and procedures at selected sites.

1.4.6 Meetings of project personnel were held frequently for planning uniform procedures and for evaluating progress.

2. RANGELAND: (JAMES K. LEWIS, INVESTIGATOR)

2.1 GENERAL OBJECTIVE: To develop the capability for using sequential multi-spectral satellite imagery for mapping kinds of rangeland and assessing seasonal or long-term changes.

2.2 SPECIFIC OBJECTIVES:

2.2.1 To evaluate the feasibility of using ERTS data for mapping the occurrence of broad kinds of range ecosystems, such as woodlands, savannas, true prairie, mixed prairie, short-grass plains and shrub communities.

2.2.2 To evaluate the feasibility of using ERTS data for mapping variations in mixed prairie ecosystems due to variations in climate, soil and management (range site and range condition).

2.2.3 To evaluate the feasibility of using ERTS data to monitor changes in range ecosystems due to season, soil moisture, grazing management or other causes.

2.2.4 To develop procedures (applicable on a world-wide scale) for mapping range ecosystems with a minimum of ground control.

2.2.5 To determine if multi-spectral imagery obtained from ERTS has practical application in rangeland inventory and classification.

2.2.6 To determine if usable inputs to management of rangeland ecosystems, either public or private, are obtainable from either single date or sequential ERTS imagery.

2.2.7 To develop rapid methods of collecting ground truth for classification and verification of ERTS imagery through photo interpretation of aircraft imagery and the use of ground-level portable radiometers and 35 mm stereograms.

2.3 VARIABLES UNDER INVESTIGATION:

2.3.1 Kinds of range ecosystems (range site and range condition) within the land form and vegetation types chosen.

2.3.2 Ground cover and vegetation biomass.

2.3.3 Vegetation phenology, height, and degree and pattern of grazing use.

2.3.4 Moisture and content of vegetation.

2.3.5 Soil characteristics

2.3.6 Soil moisture content

2.4 PROCEDURES:

2.4.1 Collect ground truth data near the time of satellite overpasses in early June, mid July and early September, corresponding to early, middle and late growth.

2.4.2 Estimate ground cover, biomass, and degree of utilization near the time of overflight at each study location by categories, including live vegetation by species, dead vegetation by species, and mulch. Proportion of rock and bare ground will also be estimated.

2.4.3 Record vegetation phenology, height and degree and pattern of grazing use near the time of overflight.

2.4.4 Measure moisture content of vegetation at each study location near the time of overflight.

2.4.5 Measure soil moisture gravimetrically near the time of overflight at depth increments of 0-5, 5-10 and 10-20 cm.

2.4.6 In addition to the ground measurements, take airborne multispectral imagery near the time of overflight.

2.4.7 Predict ground truth from satellite imagery in the following manner:

(a) Examine sequential ERTS imagery using photo interpretation techniques to attempt to extrapolate data from ground truth stations to nearby areas. Assess accuracy of these predictions from the airborne multispectral imagery and ground descriptions.

(b) Use each replication of the two range condition classes at each location to develop equations for the four bands of satellite imagery to predict ground truth. In order to avoid circularity of logic, the prediction equations were developed from one replicate and validated by testing against the other replicate.

(c) Test the prediction equations against the airborne multispectral imagery.

(d) Where delineations on the ERTS imagery were observed away from the study area, predict ground truth and use aerial photography to confirm the nature of the ground truth.

2.5 ACCOMPLISHMENTS

2.5.1 IMAGERY ACQUISITION:

(a) Four flight lines (Bennet, Cottonwood, Howes and Perkins) with a north-south orientation (Figure 2-1) were selected to provide a sample of rangeland ecosystems characteristic of western South Dakota. Imagery obtained for these flight lines during 1971, 1972, and 1973 is enumerated in Table 2-1.

2.5.2 GROUND TRUTH ACQUISITION:

(a) Ektachrome infrared prints of imagery taken by the Remote Sensing Institute aircraft in 1971 or early 1972 with Hasselblads from 10,000 feet were used to delineate range-

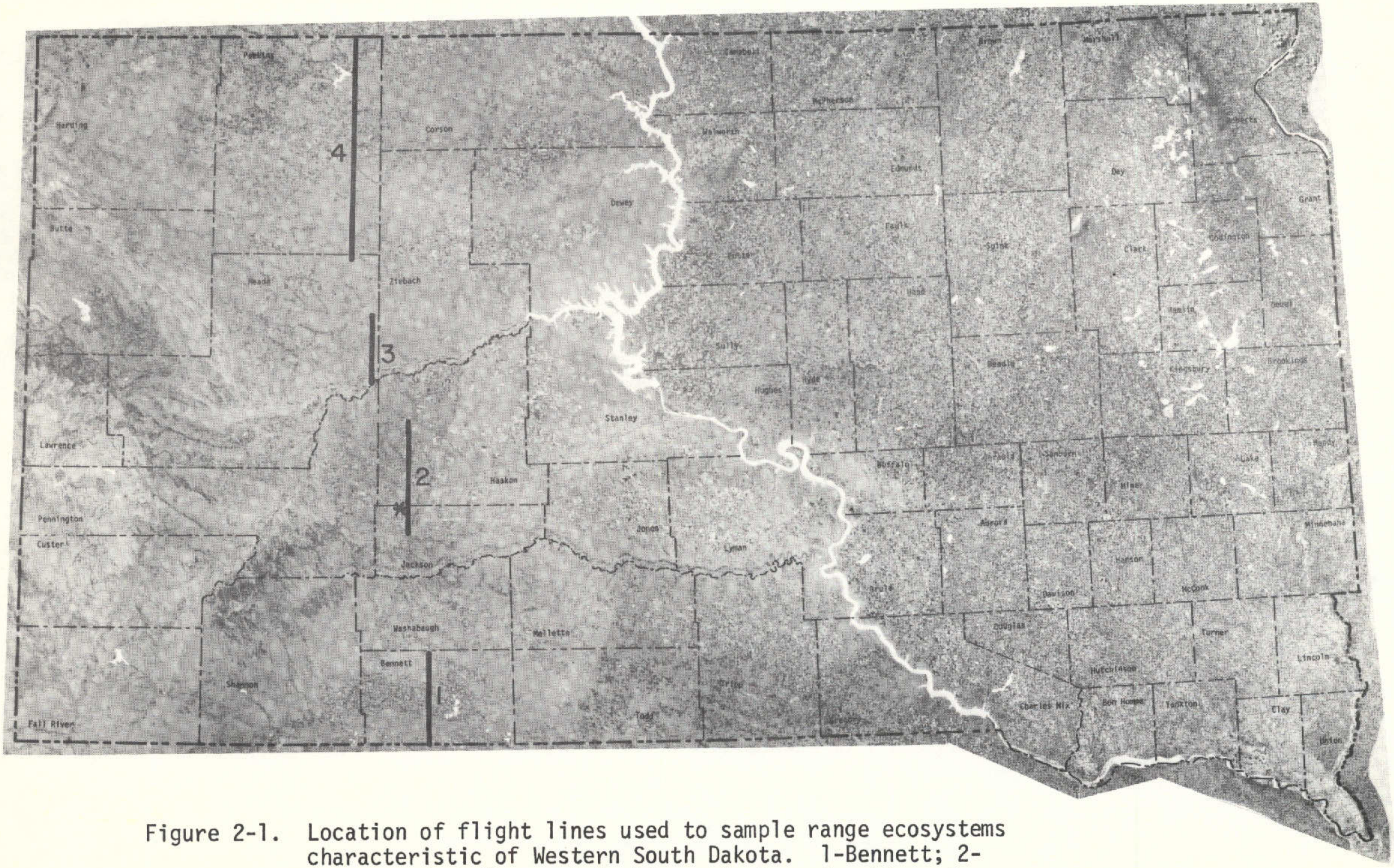


Figure 2-1. Location of flight lines used to sample range ecosystems characteristic of Western South Dakota. 1-Bennett; 2-Cottonwood; 3-Howes; 4-Perkins. * shows location of Cottonwood station.

Table 2-1. Cloud-free imagery obtained for rangeland flight lines in Western South Dakota

Date of Imagery	Sensing Platform	Type of Imagery	Flight line acquisition Bennett	Cottonwood	Howes	Perkins
July 6, 1971	RSI Aircraft	70mm CIR		*		
May 24, 1972	RSI Aircraft	70mm CIR	*	*	*	*
June 12-15, 1972	RB 57	CIR	*	*	*	*
July 24, 1972	RSI Aircraft	70mm /1	*	*	*	*
July 24, 1972	Michigan C-47	MSS	*	*	*	*
August 19, 1972	ERTS	MSS	*	*	*	*
September 6, 1972	ERTS	MSS	*	*	*	*
September 14, 1972	RB 57	CIR	*	*	*	*
October 12, 1972	ERTS	MSS	*	*	*	*
December 5, 1972	ERTS	MSS	*	*	*	*
April 5, 1973	ERTS	MSS	*	*	*	*
April 24, 1973	ERTS	MSS	*	*	*	*
July 9, 1973	ERTS	MSS	*	*	*	*
July 10, 1973	RSI Aircraft	70mm CIR		*	*	*
August 10, 1973	RB 57	CIR	*	2/	*	

* Satisfactory imagery obtained.

1-High speed Ektachrome Infrared, Panchromatic film with red (Wratten 25) and green (58) filters and infrared film with an infrared (89B) filter.

2/-Cottonwood Range and Livestock Experiment Station was covered, but the rest of the flight line was not.

land mapping units along the four flight lines.

(b) A ground truth sampling procedure was developed which consisted of:

  (1) choosing those mapping units with distinct patterns due to grazing management;

  (2) making a reconnaissance survey of these units;

  (3) taking a scenic view of the area with 35 mm Ektachrome;

  (4) taking oblique and vertical Ektachrome 35 mm stereograms with flash illumination of $\frac{1}{4}m^2$ plots within the mapping unit;

  (5) clipping the vegetation, vacuuming the mulch, and recording surface soil water in a subsample of the photographed plots; and

  (6) in the laboratory, determining standing crop of green and dead vegetation by species and the ash-free mulch.

(c) The above procedures were implemented in August, 1972 before any ERTS imagery was available on selected mapping units on the four flight lines. Special emphasis was given to sampling the experimental pastures (two each in low, medium and high range condition) on the Cottonwood Range and Livestock Experiment Station.

(d) During the summer of 1973, a Tektronix J-16 portable radiometer was modified in accordance with procedures developed by Pearson and Miller at Colorado State University to accept two uncorrected probes filtered at 6750 and 8000 angstroms with a band pass of 500 angstroms. The radiometer was mounted on a unipod and adjusted to measure reflectance from $\frac{1}{4}m^2$ plots. Readings were made at both wavelengths. Plots were then enclosed with an aluminum cone and a flash-illuminated 35 mm vertical stereogram was obtained using High Speed Ektachrome film.

A series of five plots each in different vegetation types was measured in August and mid September 1973. The plots were clipped, dried and hand separated in the laboratory into live and dead vegetation and the weight of ash-free mulch was determined.

(e) During August 1973, 1:60,000 enlargements of the area around the Cottonwood Range and Livestock Experiment Station from each of the four bands of ERTS scenes 1027-17063 August 19, 1972, 1261-17073 April 10, 1973, 1279-17073 April 28, 1973, 1315-17071 June 3, 1973, and 1351-17064 July 9, 1973 were compared with Hasselblad Ektachrome imagery at the same scale taken July 10, 1973 and with ground reconnaissance with the enlargements in hand. Enlargements of a color composite of bands 4, 5, and 7 of the same area from the July 9, ERTS imagery at a scale of 1:60,000 and 1:125,000 were also compared. ERTS scenes from winter months were of little value.

2.5.3 IMAGERY ANALYSES:

(a) During the fall and winter of 1972, strips within vertical Ektachrome slides of plots containing pure strands and mixtures of important range plant species were digitized with the Signal Analysis and Dissemination System and classified by Mr. Kaveriappa, graduate student in Electrical Engineering, using the K-Classifier and a Mode-Seeking program developed by Dr. Gerald Nelson at the Institute. (see section 6 of this report for a discussion of equipment and data handling methods). The purpose of this work was to provide rapid machine evaluation of botanical composition in the ¼m^2 plots.

(b) During the spring of 1973, photo interpretation techniques were applied to transparencies, prints and color composites of the study area to determine what elements of the soil-vegetation complex could be distinguished.

(c) In December, 1973, the Cottonwood area was masked and the transparencies of each of the four bands of ERTS scene 1351-17064, July 9, 1973, were digitized on the Signal Analysis and Dissemination System at a resolution of 36 points per mm and transmission output codes were grouped at five values per symbol and printed out. Timbered drainageways and fallow fields could be distinguished. Registration of bands was not feasible. A smaller area from the same scene was digitized with special care for registration. A grey scale was digitized, a look-up table prepared and transmission output codes transferred to density units. Printouts of bands 5 and 7 with one value per symbol in the critical range provided sufficient detail to permit more accurate registration. Values for band 7/band 5 X 100 and $\sqrt{\frac{\text{band 7-band 5}}{\text{band 7+band 5}} + 0.5}$ X 100 were calculated and printed out with one value per symbol. Three transects were laid which crossed the experimental pastures. Values lying in each pasture were tabulated and an analysis of variance was conducted.

(d) Counts for the same area at the same date for bands 5 and 7 on the computer compatible tapes were transformed to radiance and a printout with one value per symbol in the critical range was obtained for band 5, band 7, band 7/band 5 and $\sqrt{\frac{\text{band 7-band 5}}{\text{band 5+band 7}} + 0.5}$.

All of the values based on good scan lines and entirely within each pasture were hand-tabulated and an analysis of variance conducted with unequal subclass numbers.

(e) In January, 1974, the I^2S system (International Imaging Systems Model 6000 color-additive viewer) was used to examine 70 mm chips of ERTS imagery. All possible band-filter combinations were viewed at a projected image scale of 1:187,000 to see if any parameters useful in range classification could be enhanced. Only the chips from ERTS scene 1351-17064, July 9, 1973 were suitable for viewing; chips from other dates were too dense.

(f) In January, 1974, a photo interpretation comparison was made of the following imagery of the Cottonwood Range and Livestock Experiment Station: color composite of ERTS scene 1351-17064, July 9, 1973; Skylab color transparency, June 9, 1973; RB57 color infrared transparency, August 10, 1973; and color infrared print from Remote Sensing Institute 70 mm transparency, July 10, 1973. The different sensing levels were compared by rating the distinguishability and identifiability of 15 paired elements of the soil-vegetation complex corresponding to range sites, range condition classes or current utilization.

2.6 SIGNIFICANT RESULTS:

2.6.1 GROUND TRUTH ACQUISITION:

(a) Oblique 35 mm Ektachrome stereograms of ¼m^2 areas can be used to visually estimate standing crop by major range plant species. However, machine classification of species from 35 mm Ektachrome vertical transparencies (Figure 2-2) using either K-Classifier or mode seeking was only partially successful. Upper surfaces of western wheat grass leaves were confused with seedstalks of Japanese brome and lower surfaces were confused with shortgrasses.

(b) The portable 2-channel radiometer was highly successful in predicting dry green standing crop of vegetation on ¼m^2 plots in August but was less successful in predicting total dry standing crop. No relationship was found between radiometer readings and plots of very dry, mature but

Figure 2-2. A flash-illuminated, vertical 35 mm Ektachrome view of a ¼m² plot of mixed midgrass (western wheatgrass) and shortgrasses (buffalograss and blue grama). Stereograms of such views can be used to estimate standing crop by species.

still green western wheatgrass on lightly grazed uplands in August. Accordingly, these values were deleted. Five values each for shortgrasses (buffalograss and bluegrama) on uplands, shortgrasses plus western wheatgrass on uplands and western wheatgrass on lowlands were included. Results are shown in Table 2-2. The slope of the regression line was negative for reflectance in the red band and positive in the infrared. Highest correlation was obtained with the single ratio, 8000Å/6750Å, however, difference and square root of the normalized difference also had high correlation coefficients. These ratios and differences appear to be related directly to chlorophyll and indirectly to standing crop. Thus, variations in chlorophyll concentration could be expected to introduce error. Standing dead material appears to have a dilution effect, such that the change in the regression coefficient may provide an estimate of the percentage of dead vegetation. A second series of plots was studied in September. The regression coefficient of green dry weight on the ratio 8000Å/6750Å was 48.0 and the correlation coefficient was 0.848 with 30 paired values. Use of the radiometer in the field was restricted to clear days between 10 AM and 2 PM. A method of measurement of incoming radiation or a method which uses a controlled light source such as a laser beam is required to make the method operational for routine field use. Further refinement is also needed on the apparatus for making 35 mm stereograms with controlled illumination. Refinement of this methodology offers great promise for rapid measurement of standing crop of vegetation with information on botanical composition and ground cover.

2.6.2 PHOTO INTERPRETATION OF ERTS IMAGERY:

(a) Using photo interpretation techniques on ERTS imagery, broad, generalized range ecosystems can be identified and

Table 2-2. Relationship of reflectance measured with a two-channel portable radiometer to vegetation standing crop, Cottonwood Range and Livestock Experiment Station, South Dakota, August, 1973[1].

Dependent Variables	Regressors	Correlation Coefficient	Regression Coefficient	Intercept
Dry Green Standing Crop g/0.25m^2	Reflectance, 6750Å	-.765	- 2.18	- 78.9
	Reflectance, 8000Å	.500	1.54	-111.0
	Reflectance, $\frac{8000\text{Å}}{6750\text{Å}}$	.980	59.55	- 89.4
	Reflectance, 8000Å-6750Å	.970	2.20	- 64.4
	Reflectance, $\sqrt{\frac{8000\text{Å}-6750\text{Å}}{8000\text{Å}+6750\text{Å}}}$	.972	511.65	-433.4
Dry Total Standing Crop g/0.25m^2	Reflectance, 6750Å	-.723	- 4.49	-138.2
	Reflectance, 8000Å	.293	1.96	- 97.6
	Reflectance, $\frac{8000\text{Å}}{6750\text{Å}}$	.811	106.81	-129.5
	Reflectance, 8000Å-6750Å	.792	3.88	- 81.9
	Reflectance, $\sqrt{\frac{8000\text{Å}-6750\text{Å}}{8000\text{Å}+6750\text{Å}}+0.5}$	.840	957.73	-782.4

[1] All regressions were calculated from 20 pairs of observations.

discriminated. Areas with deep, loose sand; eroded areas along drainageways; interfluves dominated by deep soils; extensive areas of very heavy clay soils with low ground cover; extensive areas of solodized solonetz soils; as well as the Badlands and the Black Hills can be readily distinguished. In the vicinity of the Cottonwood Range and Livestock Experiment Station, wooded streams, fallow fields, and crop-land can be seen readily at all dates and on all bands. Discrimination between crop and rangeland areas was sharpest in early June compared with August, April or July. Crested wheatgrass pastures could usually be distinguished, expecially if more than one date in early spring is used. Go-back fields can be distinguished in some cases but not in others. In the rangeland areas, resolution is not sufficient to distinguish many ridges from ordinary uplands or from non-wooded drainageways. Extensive areas of eroded soils or ridge positions with low ground cover can generally be distinguished. Small areas differing in texture between silt and clay cannot be distinguished. Differences between pastures due to grazing management, such as illustrated in Figures 2-3, 2-4, 2-5, 2-6 can sometimes be seen in a general way. Generally, higher reflectance or increased density on a negative print is inversely proportional to standing crop. However, the difference in reflectivity of shortgrasses and midgrasses rather than amount of biomass per se may account for such image differences. While bands 5 and 7 were more useful in photo interpretation, once differences were observed they could also be found on imagery from the other bands.

(b) The use of I^2S color-additive system for viewing ERTS scenes in 70 mm format did not greatly aid photo interpretation. Contrasts visible by ordinary photo interpretation

Figure 2-3. Oblique 35 mm view of Experimental Pasture 3 taken on July 9, 1973. The area is lightly grazed and illustrates high range condition with midgrass dominance (western wheatgrass) and large standing crop (ca. 2600 kg/ha).

Figure 2-4. Oblique 35 mm view of Experimental Pasture 4 taken on July 9, 1973. The area is heavily grazed and illustrates low range condition with shortgrass dominance (buffalograss and blue grama) and low standing crop (ca. 700 kg/ha).

Figure 2-5. Vertical, flash-illuminated 35 mm view of midgrass (western wheatgrass) dominated ¼m² plot. Stereograms of such views are a valuable aid in determining botanical composition.

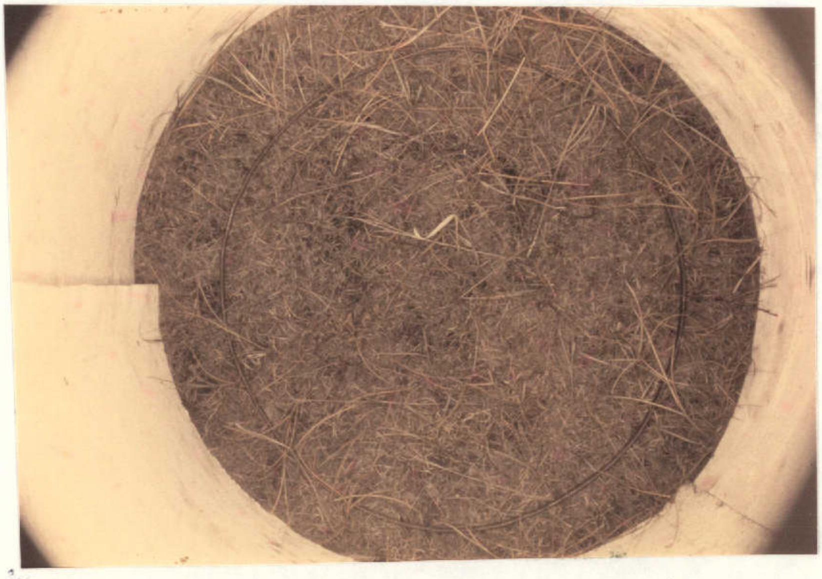


Figure 2-6. Vertical, flash-illuminated view of shortgrass dominated (buffalograss and blue grama) ¼m² plot. This photo and the one in Figure 2-5 are parts of stereopairs taken in conjunction with the portable 2-channel radiometer sampling.

could be enhanced to some degree but little additional detail could be distinguished. Viewing of projected images of all possible band-filter combinations failed to reveal a combination which would provide a signature for range sites or range condition classes. The band-filter combinations which were most useful are given in Table 2-3. A decrease in brightness of the projected image when three or more bands and filters were used is a serious drawback of the system. The I^2S system does offer a quick and inexpensive method of viewing and evaluating ERTS imagery. Also, by using superimposed sequential imagery of the same scene, it would be possible to determine changes in land use (range to cropland or vice versa).

(c) If maps of geological features and soils are superimposed on the ERTS imagery, refinements in the existing maps are often possible. Since many range ecosystem characteristics are correlated with geology and soils, these maps have important range applications. Thus, photo interpretation of ERTS imagery can provide much valuable information on the distribution of range ecosystems in relation to broad soil groups, drainage basins and other geographical and political or sociological divisions. However, photo interpretation from the ERTS imagery was not sufficiently precise to provide useful inputs for management of individual ranches or public land allotments.

2.6.3 DIGITAL ANALYSIS OF ERTS IMAGERY:

(a) Wooded drainageways, fallow fields and some cultivated fields could be distinguished on a printout of transmission output codes for the digitized transparencies of bands 5 and 7. However, no difference could be seen

Table 2-3. Band-filter combinations which were judged most useful in viewing projected images of ERTS scenes on the I^2S system. Ratings (P=poor; F=fair; G=good; VG=very good) of the rendition of some landscape features are given.

Band-filter combination[1]	Cultivated fields	Shortgrass dominated experimental pastures	Major wooded drainageways	Major non-wooded drainageways	Broad soil groups	Ponds
5 G	G	P	G	F	F	P
4 B + 5	G	F	G	F	F	P
4 B + 6	F	G	F	P	F	G
4 B + 7	VG	G	G	G	VG	G
5 + 6 R	VG	G	VG	G	F	P
4 B + 5 + 7	G	G	F	P	P	G
5 G + 6 R + 7	F	F	G	P	F	G
4 B + 5 G + 7 R[2]	G	F	G	F	G	G

[1] G = green filter; B = blue filter; R = red filter

[2] Ability to distinguish hampered by low light intensity of projected image.

in the range areas. Ratioing the bands was not helpful. Much less detail could be seen than with negative enlargement of the transparencies. When the transmission output codes were transformed to density values and printed with one value per symbol, slightly more detail could be seen from bands 5 and 7 than could be seen on the negative prints. Values from transects across the experimental pastures were analyzed statistically. Results are shown in Table 2-4. Mean densities are very similar, however, the variability within transects is extremely low. The very large number of points digitized produces one value for approximately .08 hectares whereas a resolution element from ERTS is about .40 hectares. Thus, digitization serves to enhance the small differences. While both bands 5 and 7 show significant differences, band 5 has a higher F value for transect 1. However, density means for band 5 do not place the most similar pastures together. Band 7 is more consistent in this respect. The ratio and the square root of the normalized difference were of less value.

(b) A comparison of radiance values from the pastures calculated from the counts on the computer compatible tapes is shown in Table 2-5. While the F value is slightly higher and the standard deviation slightly lower for band 7 than for band 5, only the two low range condition pastures are properly discriminated. Information from bands 7 and 5 is redundant and when combined as a ratio or as the square root of the normalized difference, the F value is lowered and discrimination is poorer. Using the tapes, we can quantify approximately what can be seen in negative enlargements of bands 5 and 7. These data suggest that discrimination is between different

Table 2-4. Comparison of density values from bands 5 and 7 of ERTS scene 1351-17064, July 9, 1973, across the experimental pastures, Cottonwood Range and Livestock Experiment Station, South Dakota

Range Condition				Fair-		Good		Excellent-	
Pasture				1	4	5	2	6	3
Area, ha				29.1	32.4	53.8	57.1	74.1	74.1
Generalized dry standing crop, kg/ha				800	700	1400	1400	2600	2600
Approximate green, %				75	75	70	70	65	65
Shortgrasses, %				85	95	65	65	40	40
Transect Measure	Statistic			Mean density values[1]					
	F	P	$S_{\bar{x}}$						
1 Band 5	188.5	< .001	<.002		1.321^{d}	1.345^{b}		1.330^{c}	1.369^{a}
Band 7	27.1	< .001	<.003		1.222^{c}	1.234^{b}		1.246^{a}	1.250^{a}
Band 7/Band 5	17.1	< .001	<.002		$.924^{b}$	$.919^{bc}$		.937A	$.913^{c}$
$\sqrt{\frac{7-5}{5+7}} + 0.5$	13.4	< .001	<.001		$.734^{b}$	$.737^{a}$		$.730^{b}$	$.739^{a}$
	t	p	$s_{\bar{d}}$						
2 Band 5	20.2	< .001	<.002	1.311				1.350	
Band 7	10.6	< .001	<.002	1.198				1.222	
Band 7/Band 5	3.6	< .001	<.002	.914				.905	
$\sqrt{\frac{7-5}{5+7}} + 0.5$	3.6	< .001	<.001	.737				.741	
3 Band 5	16.6	< .001	<.002	1.311			1.352		
Band 7	18.6	< .001	<.002	1.190			1.225		
Band 7/Band 5	0.2	N.S	.002	.905			.905		
$\sqrt{\frac{7-5}{7+5}} + 0.5$	0.4	N.S	.001	.740			.740		

[1] Values in the same row with the same superscript do not differ significantly at the .01 level of probability.

Table 2-5. Comparison of radiance values (m-watts/cm^2-str-μm) from computer compatible tapes of the experimental pastures at Cottonwood Range and Livestock Experiment Station, South Dakota, on ERTS scene 1351-17064 July 9, 1973[1].

Range Condition				Fair-		Good		Excellent-	
Pasture				1	4	5	2	6	3
Area, ha				29.1	32.4	53.8	57.1	74.1	74.1
Generalized dry standing crop, kg/ha				800	700	1400	1400	2600	2600
Approximate green, %				75	75	70	70	65	65
Shortgrasses, %				85	95	65	65	40	40
Measure	Statistic F	Statistic P	Statistic $S_{\bar{x}}$						
Band 5	22.5	<.001	1.557	29.90^{a}	30.81^{a}	28.11^{b}	28.12^{b}	28.31^{b}	28.45^{b}
Band 7	25.6	<.001	1.432	28.23^{a}	28.57^{a}	26.83^{b}	26.08^{c}	27.11^{b}	26.06^{c}
Band 7/ Band 5	4.0	<.01	.076	$.954^{ab}$	$.930^{abc}$	$.957^{ab}$	$.929^{bc}$	$.960^{a}$	$.918^{c}$
$\sqrt{\frac{7-5}{5+7}+0.5}$	4.4	<.01	.028	$.686^{a}$	$.679^{a}$	$.690^{a}$	$.680^{a}$	$.691^{a}$	$.675^{b}$

[1] Values in the same row with the same superscript do not differ significantly at the .01 level of probability.

proportions of shortgrasses rather than in amount of standing crop. The reason for the very poor performance of the radiance ratio of band 7/band 5 for discriminating standing crop of pastures and the very excellent performances of the reflectance ratio of 8000Å/6570Å discriminating standing crop on small plots is not understood. Ratios of radiances of band 7/band 5 from space was always less than one. Ratios of reflectance of 8000Å/6750Å from near the ground ranged from approximately 1.5 to 2.5

2.6.4 COMPARISON OF SPACE AND AIRCRAFT IMAGERY:

(a) Parameters of the imagery used in a photo interpretation comparison of imagery from sensing platforms at different elevations is given in Table 2-6. In many respects, the variation in type and date of the imagery make such a comparison unfair. In general terms, however, an idea is obtained of the rangeland parameters best portrayed by each level of imagery. The relative ease with which contrasting features of the soil vegetation complex could be distinguished and identified are presented in Table 2-7. Portions of the imagery at identical scales and keys to selected features are presented in Figures 2-7 and 2-8.

(b) Many features pertaining to range sites can be readily seen on ERTS imagery and better yet on the lower elevation Skylab imagery. Use of sequential space imagery could in some cases enhance the ease of distinguishing parameters. In general, however, space imagery was not effective for distinguishing or identifying elements pertaining to range condition or current utilization. Both RB57 and low-level aircraft imagery allow identification of elements useful in classification of range condition. The aircraft imagery

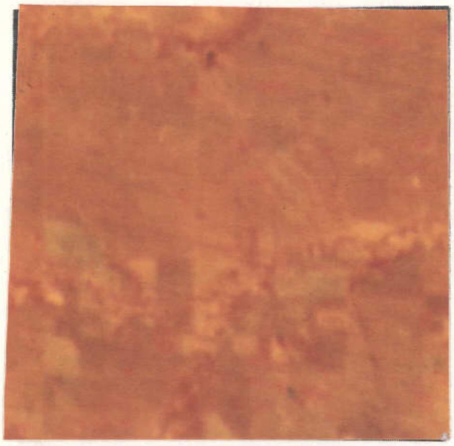
Table 2-6. Parameters of imagery used in assessment of ability to identify and distinguish elements in the rangeland soil-vegetation complex.

Sensor Platform	ERTS-1	SKYLAB	RB57	RSI Beechcraft
Sensor System	MSS	S190-B	Zeiss	Hasselblad
Mission Date	7/10/73	6/9/73	8/10/73	7/10/73
Original Image Type	B & W Trans	SO-242 color	CIR Trans	CIR Trans
Original Image Scale	1:1,000,000	1:960,000	1:60,000	1:65,700
Interpreted Image Type	Color comp. print	CIR Trans	Color Trans	CIR Print
Interpretation Format	9" x 9"	9" x 9"	9" x 9"	7½" x 7½"
Interpretation Scale	1:125,000	1:460,000	1:60,000	1:18,700
Magnification Used		10 x	10 x	
Synoptic View (per frame)	160 x 160 km	106 x 106 km	13.5 x 13.5 km	3.6 x 3.6 km

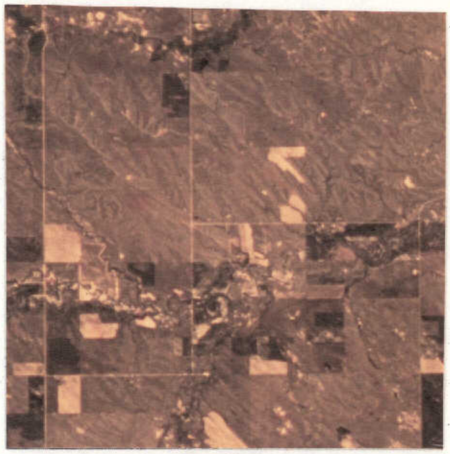
Table 2-7. Relative Ability to Distinguish and Identify Contrasting Elements of the Rangeland Soil-vegetation Complex on Space and Aircraft Imagery.

Distinguishing two contrasting elements in the soil-vegetation complex	Elements have correspondence with: Range Sites	Range Condition Classes	Current Utilization	Relative ease of distinguishing (D) and Identifying (I) contrasting elements in imagery: ERTS D	ERTS I_1	ERTS I_2	SKYLAB D	SKYLAB I_1	SKYLAB I_2	RB57 D	RB57 I_1	RB57 I_2	RSI Aircraft D	RSI Aircraft I_1	RSI Aircraft I_2
Distinguish interfluves (I_1) from breaks of major drainageways (I_2)[a]	yes	NA	NA	...	...	...	...	...	...	...	...	...	...	...	...
Distinguish wooded drainageway (I_1) with large amount of run-in water from non-wooded (I_2)	yes	NA	NA	...	...	..	...	...	...	...	...	...	...	...	...
Distinguish trees (I_1) from shrubs (I_2)	yes	yes	NA	.	.	.	.	.	.	...	...	...	...	...	...
Distinguish non-wooded drainageway (I_1) with large amount of run-in water from those with small amount (I_2)	yes	NA	NA	.	.	.	...	...	...	...	...	...	...	...	...
Distinguish slopes (I_1) from small drainageways (I_2)	yes	NA	NA	.	.	.	...	...	...	...	...	...	...	...	...
Distinguish ridgetops (I_1) from slopes (I_2)	yes	NA	NA	.	.	.	...	...	...	...	...	...	...	...	...
Distinguish broad groups of soil parent materials - shales (I_1) from sandstone (I_2)[a]	yes	NA	NA	...	..	..	...	..	..	..	..	..	.	.	.
Distinguish panspots (I_1) from all other range sites	yes	NA	NA	..	..	NA	..	..	NA	...	...	NA	...	...	NA
Distinguish old (50+ years) go-back fields (I_1) from undisturbed range (I_2)	yes	yes	NA	.	.	.	.	.	.	.	.	.	..	..	..
Distinguish recent (less than 50 years) go-back fields (I_1) from undisturbed range (I_2)	yes	yes	NA	..	..	..	..	..	..	..	..	..	...	..	..
Distinguish planted crops (I_1) from native range (I_2)[b]	NA	NA	NA	..	..	..	...	.	..	...	..	..	...	...	...
Distinguish planted stands of crested wheatgrass (I_1) from native range (I_2)[b]	NA	NA	NA	..	..	..	...	.	..	..	.	..	...	..	..
Distinguish shortgrass dominance (I_1) from midgrass dominance (I_2) (on basis of standing crop)[b]	yes	yes	yes	..	..	..	..	..	..	...	...	...	...	...	...
Distinguish range areas of high standing crop (I_1) from those with low standing crop (I_2)[b]	NA	yes	yes	..	..	..	..	..	..	...	...	...	...	...	...
Distinguish range areas of intermediate production (I_1) from areas with high or low production (I_2)[b]	NA	yes	yes	.	.	.	.	.	..	..	..	...	...	..	...

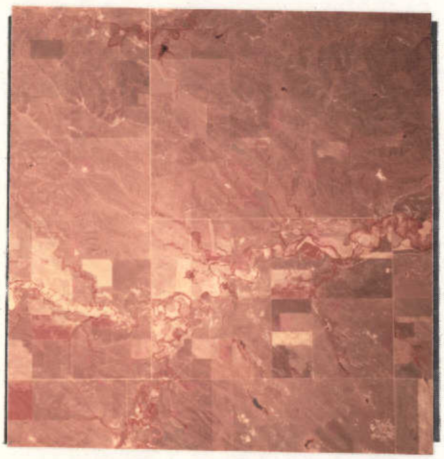
a - Broad synoptic view required - several frames necessary for RB57 and RSI aircraft imagery
b - Sequential imagery during season would greatly increase ease of distinguishing and identifying
D - Distinguishable - able to discriminate an image entity from the surrounding matrix
I - Identification - ability to classify an image by its unique characteristics such as color, tone, texture, shape, pattern size, association or other quality
... - easily distinguishable or identifiable
.. - marginally distinguishable or identifiable
. - not distinguishable or identifiable
NA - not applicable



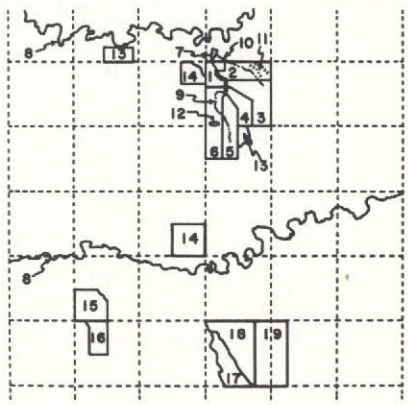
A. ERTS color composite



B. Skylab color



C. RB57 Color Infrared



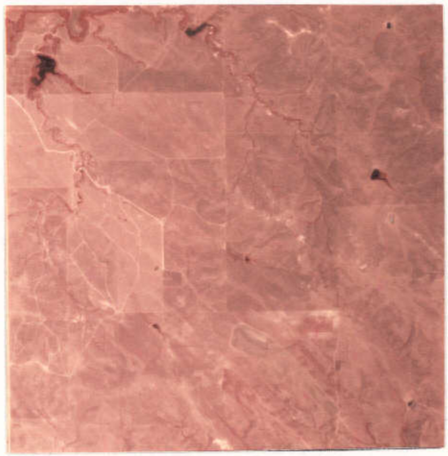
D. Key

Figure 2-7. Scenes from ERTS, Skylab and RB57 imagery at a scale of 1:125,000 showing the vicinity of the Cottonwood Range and Livestock Experiment Station. A line drawing key to important features used in judging relative worth of imagery for rangeland classification is shown in D. Most of the area shown is rangeland. (see next page for code to key)

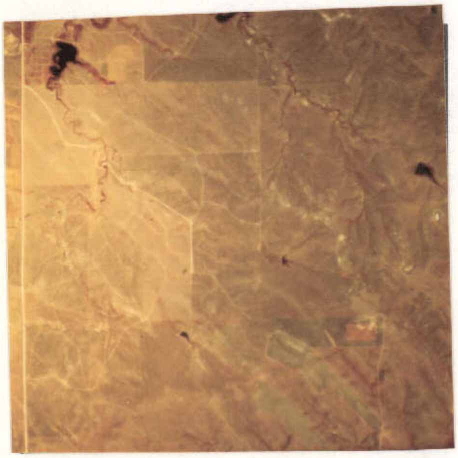
Codes	Key		
1	Experimental Pasture	1;	shortgrass dominance, low standing crop (ca. 800 kg/ha).
2	" "	2;	mid and shortgrass dominance, medium standing crop (ca. 1400 kg/ha).
3	" "	3;	midgrass dominance, high standing crop (ca. 2600 kg/ha).
4	" "	4;	shortgrass dominance, low standing crop (ca. 700 kg/ha).
5	" "	5;	mid and shortgrass dominance, medium standing crop (ca. 1400 kg/ha).
6	" "	6;	midgrass dominance, high standing crop (ca. 2600 kg/ha).
7	Pond		
8	Wooded drainageway		
9	Example of large non-wooded drainageway		
10	Example of small non-wooded drainageway		
11	Example of ridge position		
12	Old (more than 50 years) go-back field		
13	Recent (less than 50 years) go-back field		
14	Seeded crested wheatgrass		
15	Alfalfa		
16	Sorghum		
17	Fallow cultivated field		
18	Ungrazed rangeland, midgrass dominance, high standing crop		
19	Grazed go-back range, midgrass dominance, reduced, medium standing crop		

Dashed lines denote section boundaries (code to key on figure 2-7)

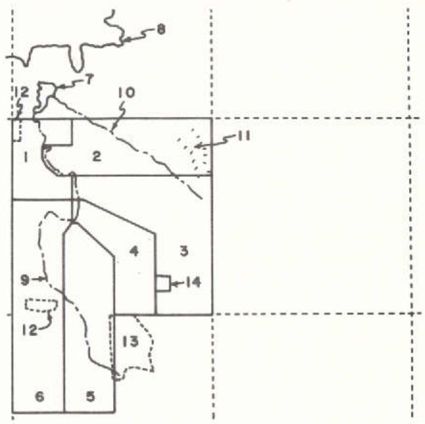
A. Skylab color



B. RB57 Color Infrared



C. RSI 70 mm Color Infrared



D. Key

Figure 2-8. Scenes from Skylab, RB57 and RSI 70 mm imagery at a scale of 1:60,000 showing the experimental pastures on the Cottonwood Range and Livestock Experiment Station. A line drawing key to important features used in judging relative worth of imagery for rangeland classification is shown in D. (see next page for code to key)

ORIGINAL PAGE IS
OF POOR QUALITY

Codes	Key		
1	Experimental Pasture	1;	shortgrass dominance, low standing crop (ca. 800 kg/ha).
2	" "	2;	mid and shortgrass dominance, medium standing crop (ca. 1400 kg/ha).
3	" "	3;	midgrass dominance, high standing crop (ca. 2600 kg/ha).
4	" "	4;	shortgrass dominance, low standing crop (ca. 700 kg/ha).
5	" "	5;	mid and shortgrass dominance, medium standing crop (ca. 1400 kg/ha).
6	" "	6;	midgrass dominance, high standing crop (ca. 2600 kg/ha).
7	Pond		
8	Wooded drainageway		
9	Example of large non-wooded drainageway		
10	Example of small non-wooded drainageway		
11	Example of ridge position		
12	Old (more than 50 years) go-back field		
13	Recent (less than 50 years) go-back field		
14	Ungrazed, permanent, exclosure		

Dashed lines denote section boundaries

(code to key on figure 2-8)

is less useful and convenient than space imagery in distinguishing broad soil groups and topographic features best seen in a broad synoptic view.

(c) Space imagery provides a valuable tool for laying out the broad outlines of different range ecosystems. Boundaries are discernible which might well be obscured and missed in the greater detail of aircraft imagery. Even aircraft imagery does not provide enough resolution to permit determination of botanical composition, an indispensable parameter for assigning range condition classes. This information must come from reconnaissance or ground-level photos or from airborne multispectral scanner data. Thus, at the present state of the art, range classification inputs useful in management must be derived from several levels of imagery, each of which can contribute essential elements with greater precision and accuracy at a saving in cost over the conventional ground surveys.

2.7 SUMMARY OF WORK PERFORMED AND CONCLUSIONS:

2.7.1 Procedures for reconnaissance and sampling of rangeland mapping units were developed for collection of ground truth data. A two-channel radiometer similar to that described in 1973 by Miller and Pearson, Colorado State University has been tested and found to be suitable for prediction of dry green standing crop when used near midday on clear days. A technique and prototype equipment have been developed for taking 35 mm vertical Ektachrome stereograms with controlled illumination. Use of K-Classifier and mode-seeking programs on digitized transparencies to determine botanical composition and ground cover was not successful.

2.7.2 Large, generalized range ecosystems such as sands, eroded drainageways, interfluves, etc. can be readily seen on ERTS transparencies.

2.7.3 Photo interpretation of negative enlargements from all four bands of ERTS imagery and from different dates at a scale of 1:60,000 showed that wooded drainageways, large barren areas, fallow fields, cultivated crops, crested wheatgrass fields and some go-back fields could be distinguished. In rangelands, most ridges, ordinary uplands and non-wooded drainageways could not be distinguished. Grazing management differences could be distinguished in a general way. Generally, increased density of negative prints was inversely proportional to standing crop. Differences were easier to see on color composites.

2.7.4 Viewing of ERTS imagery in 70 mm format on the I^2S system at all possible band-filter combinations at a projected image scale of 1:187,000 revealed that only a slight enhancement of contrast visible on negative or color composite prints was possible. No additional detail was rendered visible.

2.7.5 Statistical evaluation of density values of range pastures from ERTS transparencies and of radiance values of range pastures from ERTS computer compatible tapes show that the differences seen on the transparencies can be quantified in a general way. However, very large differences in vegetation standing crop across fence lines were not always detected and in some cases density and radiance values were in the wrong order. In the rangeland area, the bands seemed to be redundant and no information was gained from the ratio band 7/band 5 or for the $\sqrt{\frac{\text{band 7-band 5}}{\text{band 7+band 5}} + 0.5}$.

2.7.6 Photo interpretation of the same scene on ERTS, Skylab, RB57 and low-level 70 mm imagery showed that many of the contrasting soil-vegetation elements of range ecosystems which pertain to range sites can be distinguished and identified on space imagery. Elements pertaining to range condition and utilization are distinguishable on both high and low level aircraft imagery. Aircraft imagery is much less convenient than space imagery for detecting boundaries of broad soil groups, major drainageways and other boundaries defining generalized range ecosystems.

2.7.7 The ERTS imagery appears to be very useful for refining boundaries of major soil and vegetation types and for distinguishing cropland from rangeland. However, greater resolution with more and narrower bands appears to be needed to provide information for use in range management on such items as range sites, range condition classes, vegetation standing crop and botanical composition.

2.8 RECOMMENDATIONS FOR FUTURE STUDIES:

2.8.1 Remote Sensing data are accumulated rapidly over large areas. It follows that to evaluate and characterize remote sensing data, ground truth data must be collected and processed with great rapidity. Thus, there is a great need for continued development of ground truth collection capability. The two-channel portable radiometer shows much promise as a quick, efficient instrument for measurement of the standing crop of green vegetation. The radiometer, coupled with the collection of 35 mm stere-grams, can provide a measure of green standing crop and botanical composition on the same plot. However, there are several aspects which need further investigation and development.

(a) The apparatus needs to be tested in a wider variety of vegetation types encompassing an extended range of biomass differing in both quantity and species composition.

(b) Regression coefficients appear to change as the ratio of dead to green material changes. The possibility of using the change in the regression coefficient as a measure of dead material needs to be thoroughly explored. If both green and dead material could be measured simultaneously by the same instrument, a measure of total above-ground biomass would be achieved at a great saving in time. Also, the ability to measure dead as well as green biomass would extend the season within which useful data could be collected.

(c) At present, use of the radiometer is restricted to the middle portion of clear days when sunlight is maximal. This greatly restricts data acquisition on both a daily and seasonal basis. There are two possibilities for correcting this deficiency which need to be explored: (1) the use of a filtered radiometer to measure intensity of the pertinent incoming wavelengths: (2) development of a controlled light source which would eliminate dependence upon sunlight. Development of a controlled light source would offer the greatest potential for climatic-independent sampling.

(d) If the radiometer-stereogram sampling technique were to measure up to expectation, a rapid means of processing 35 mm photographic images would be a necessity to obtain a smooth data flow. While attempts at species identification by machine classification of Ektachrome images were not successful, research in this area should be continued. The use of density values rather than output codes; the construction of holographic type images from stereograms followed by machine processing; development and refinement of mode-seeking algorithims and other machine classificatory techiques should be investigated. This could well be construed as a priority area because application is not limited to 35 mm ground-level imagery. It is quite possible that much information on rangeland parameters could be derived directly from aircraft or satellite imagery if appropriate machine classification techniques were at hand.

2.8.2 The ERTS imagery has not been fully explored as a source of rangeland parameters.

(a) While bands 5 and 7 were the apparent logical choices for the application of ratioing, other combinations have not been tried. Ratios such as band 5/band 6, band 4/band 6, band 4/band 7, etc., should be examined at more than one date, at least on a limited basis, so that the apparent redundancy of the bands in rangeland areas is either proved or disproved.

(b) The effect of background radiance from different kinds of rangeland soils on ERTS scenes should be investigated. Generally, the smaller the vegetation cover, the greater the contribution of soil radiance and the more difficult to detect vegetation differences from the imagery. Methods other than ratioing bands 5 and 7 must be tried.

(c) Old and recent go-back fields are an extensive and important part of the current rangeland complex in western South Dakota. The ability to distinguish some go-back fields but not others on ERTS imagery indicates that the imagery is quite sensitive to some reflectance modifying factor in the soil-vegetation complex of old fields. Determination of this factor, or factors, might provide clues as to how to better interpret ERTS imagery as well as possibly providing data useful in management.

2.8.3 The multi-spectral scanner data collected by the Michigan C-47 has not been studied. This level of sensing would appear to have a great potential for the quantification of rangeland parameters. Another, and perhaps prime reason, for study of the imagery is that it may offer clues as to why a wavelength ratio (8000Å/6750Å) which measures green vegetation accurately at ground level fails to do so when measured in space. Knowledge on this point is indispensable if recommendations for the design of sensors capable of detecting vegetation parameters are to be made.

2.8.4 We are sadly deficient in information pertaining to reflectance characteristics of native rangeland vegetation. Some information is available from the studies at Colorado State University but this is limited to shortgrasses. It would appear that adequately sensitive sensor systems can be designed best when it is known what portion of the electromagnetic spectrum is reflected from different plant species. Thus, an intensive program to quantify the absorption and reflectance characteristics of at least the major range grasses and forbs would provide valuable inputs to a remote sensing program, both in design and interpretation.

3. CROPLAND: (DR. HORTON, INVESTIGATOR JAMES HEILMAN, GRADUATE ASSISTANT)

3.1 INTRODUCTION: Land for the production of food is essential to a nation's agricultural productivity. The crops grown on the land and the food and fiber produced determine a nation's ability to feed itself. Man constantly seeks ways to find out how much land is planted to different crops and the progress of growth. Crops information is so important that our government has established a Crop Reporting Service to gather information about the nation's food supply. The ERTS satellite and other satellite systems offer much promise in assisting the inventory of crop resources. The synoptic view of the land, sequential coverage, and seasonal surveillance capabilities of the ERTS satellite are desirable characteristics for a resource inventory system.

3.2 GENERAL OBJECTIVE: Assessment of the usefulness of ERTS data for crop resource inventory.

3.3 SPECIFIC OBJECTIVES:

3.3.1 To obtain "signatures" for specific crops which are common to the Northern Great Plains.

3.3.2 To determine species identification capabilities with ERTS data using crop "signatures", tested statistical techniques, and time dependent parameters obtained by combining data from several ERTS passes.

3.3.3 To determine the parameters obtainable from ERTS data that are useable as inputs to a model for evaluating crop resources from areal integrated image radiances.

3.3.4 To test ERTS data against ground truth to determine if satellite imagery can be applied for detection of vegetation stresses that cause crop variability.

3.4 VARIABLES UNDER INVESTIGATION:

3.4.1 Crop Species-The species investigated were alfalfa, corn, oats, soybeans, and mixed species meadow.

3.4.2 Growth Stage-The crops were studied at stages of growth from planting to maturity. Date of planting and date of maturity were variable according to normal field practices.

3.4.3 Soil Variability-The crops studied were grown on upland and bottomland soils which varied in depth, texture, fertility, and water content.

3.4.4 Season-ERTS images studied included dates from May to September spanning two different crop production seasons.

3.4.5 Crop Management-The fields investigated varied in tillage practices, plant population, varieties, fertility practices, and weed control according to normal farm management.

3.4.6 Imagery-The imagery used was standard product ERTS imagery which included normal variation in atmospheric attenuation and image quality. Aircraft imagery was also used to provide ground truth and to aid in field boundary detections.

3.5 PROCEDURES: Rapid inventory of crop resources over broad regions using satellite imagery can best be done using machine assisted techniques. Therefore, the crops portion of this study concentrated on digitized imagery and computer based data handling techniques. In order to test and calibrate computer programs, accurate ground-truth about the study area was essential.

3.5.1 Study Area The 3.2 km by 14.4 km study area shown in Figure 3-1 was located in Clay County in southeastern South Dakota. The study area was selected because it contained soils and crops representative of those found throughout Clay County

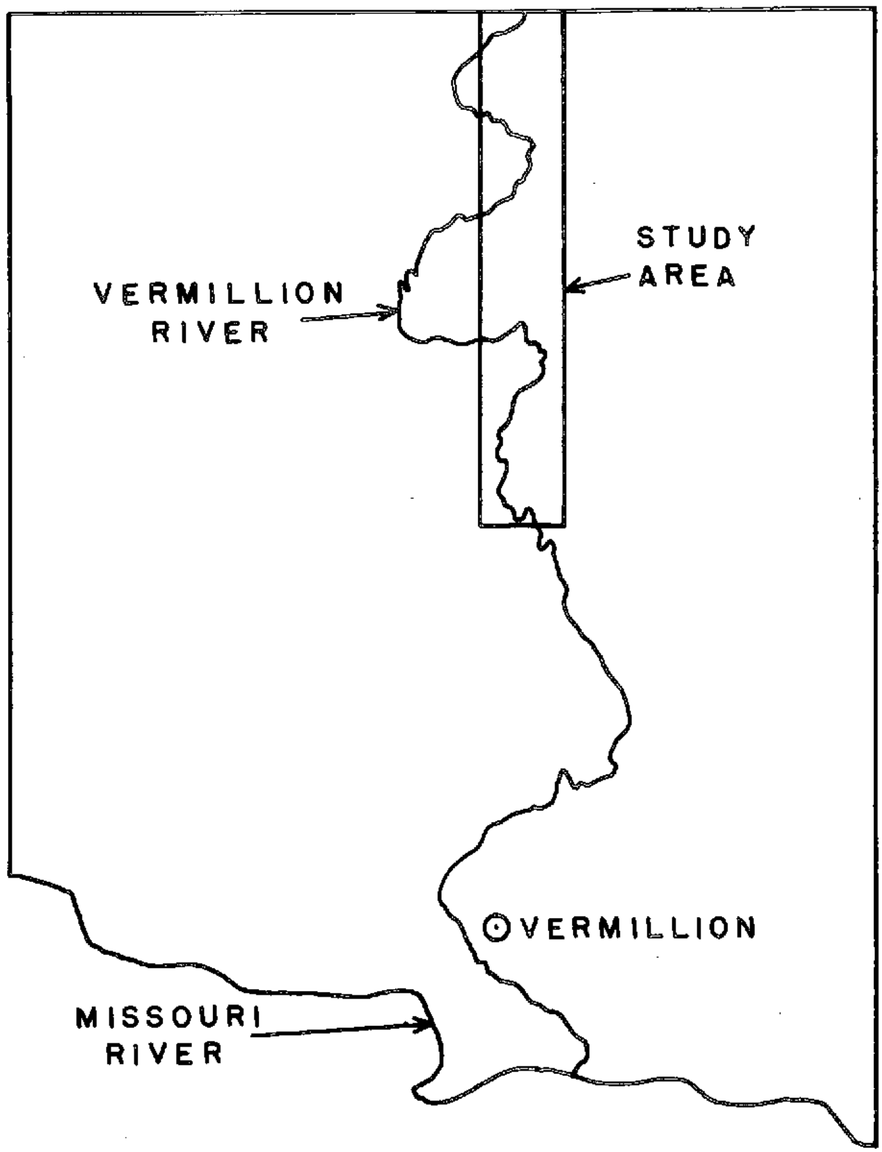


Figure 3-1. A map of Clay County showing the location of the study area.

and the southeastern part of the state. The two major soils in the study area are the alluvial, clayey Luton soils found in the Vermillion River flood plain and the silty Egan-Wentworth-Viborg soils found in the uplands adjacent to the flood plain. The major crops in the study area are corn, soybeans, and oats with alfalfa and pasture land occupying the remaining portions of the study area. The climate of Clay County can be described as sub-humid with an average annual precipitation of 63.17 cm. The length of the growing season ranges from 150 to 160 days.

3.5.2 Ground Truth Procedures. The initial survey of the study area was conducted in July of 1972 using C-47 imagery at a scale of 1:22,000 to determine field size and location and ground based observations to determine the crop species within the field boundaries. Most of the 1973 field boundaries remained unchanged from 1972 although the crops within the boundaries were changed. Ground surveys were again used to determine the species within the field boundaries. The field boundaries that had changed from 1972 were mapped from the air at an altitude of 610 m. On the basis of these initial surveys, certain fields representative of each major crop species and soil type within the study area were selected as test fields. At the time of each ERTS overpass, crop parameters consisting of plant height, row spacing, row direction, and stage of maturity were measured for each test field. In addition, relative measurements of percent ground cover, stress, and weed condition were recorded. Concurrently with the above measurements, ground based color photographs were taken.

3.5.3 Digital Analysis of the Study Area. In order for pattern recognition algorithms to be used for image analysis, the image must be quantified. The quantification or digitizing was accomplished using Signal Analysis and Dissemination

Equipment (SADE) located at the Remote Sensing Institute (see Appendix F. of this report for equipment description). The system's image digitizer, utilizing an image dissector tube, permitted the digitization of the imagery into 256 levels (output codes). The maximum resolution of digitization was 36 resolution elements (pixels) per millimeter. To prepare the ERTS images for digitizing, a portion of each positive transparency corresponding to the study area was masked so that only the desired region was digitized. The masks were constructed by initially covering an enlarged ERTS photograph with a clear mylar sheet upon which the study area was inked in. The enlargement was used to facilitate the inking process since the boundaries of the study area were more readily visible than on the original transparency. The inked in area was then reduced to the scale of the original ERTS transparency using a photographic enlarger, and a negative of the reduced mask was then made. The final product, was a transparent region corresponding to the study area at a scale of 1:1,000,000 surrounded by an opaque border to prevent any extraneous area from being digitized. Prior to mounting the masks on the images, the masks and the ERTS transparencies were cleaned using a spray type film cleaner. The masks were mounted on the positive transparencies using opaque photographic tape. Prior to digitization, the light level of the digitizer was optimized for the density range of each transparency. The images were registered with an interface system on the color monitor of SADE using the alignment controls on the digitizer. The four transparencies for each particular date of interest were successively digitized at a resolution of 36 pixels per millimeter, transmitted to an IBM 370 computer, and stored on magnetic tape for future analysis. A map of the study area output codes for each ERTS wavelength band was printed out on computer paper using a "symbol" program. This program divided the possible range of output codes from 0 to 255 into increments of five values each and assigned a symbol to represent each increment. Symbols were printed rather than actual output code values to reduce the size of the printout. The test fields were located on the computer maps. Symbols for each test field were converted into their corresponding output codes for use in pattern recognition algorithms using a "choose" program. The "choose" program converted a matrix of symbols within a test field to actual output codes using the location and size of the matrix measured on the computer maps as inputs into the program. Accurate registration was assumed so that matrix coordinates were only measured on one ERTS band printout for each date of imagery analyzed. Data from the test fields were analyzed using the K-Class classifier, (see section 6 for discussion of K-Class) for all possible combinations of features (ERTS wavebands) to determine which features gave the most accurate classification results. K-Class, a minimum distance to the means classifier, made decisions based on the means and variances of the test field data. The test field data were used to extrapolate to a classification of the entire study area using the features which gave the best classification results as determined by K-Class. If a combination of features yielded the best results, K-Test was used to classify the study area. K-Test refers to the K-Class classifier which has been trained using a set of test data called a training set. For the classification of the study area, the test field data acted as the training set. When single features were found to provide the best results, a visual analysis of the histograms of the test field data was used to determine the decision boundaries between classes. In addition to K-Class, a pattern recognition algorithm called "mode seeking", (see section 6 for discussion) was used to analyze digitized ERTS imagery. The non-supervised "mode seeking" algorithm located an instructed number of modes up to 20 in a set of data. The algorithm then classified each data point as to which mode it belongs. A computer printout of a "mode seeking" map was used for analysis. Finally, an attempt was made to enhance vegetation and suppress soil background using a ratio of output codes of two different ERTS bands. The ratio used was (Band 6/ Band 5) x 100. The justification for using this particular ratio was that vegetation was more reflective than soil in band 6 and had a similar reflectance to bare soil in band 5.

3.5.4 Land Use Analysis of Clay County. The ERTS-1 imagery of Clay County was digitized at a resolution of 18 pixels per millimeter. The county was then classified into the various crop species using decision boundaries determined from the histograms of the test field data in the study area. A land use map of Clay County identifying vegetative types was prepared from the classification results. To determine the accuracy of the classification, the results using ERTS imagery were compared with figures provided by the Agricultural Stabilization and Conservation Service (ASCS).

3.5.5 Influence of Soil on Crop Resources Study. The signatures of crop canopies contain soil influences that appear as crop variables. The soil background gives a radiance effect depending upon colors, surface, texture, and water content. In addition, the soil influences vegetation stresses which may be related to lack of water, too much water, insufficient rooting depth, or inadequate supply of nutrients. A detailed study of the influence of soil variations on crop radiances was conducted and is reported separately in Section 5.0 of this report.

3.6 ACCOMPLISHMENTS:

3.6.1 Ground Truth. A ground truth map of the study area was prepared to show field boundaries, crop species, major natural or man-made features, and location of test sites. Ground surveys and aerial photographs were used to acquire additional information about the crops or to correct field boundaries.

3.6.2 ERTS-1 Imagery Analysis. ERTS-1 imagery of the following dates were analyzed:

Table 3-1. Dates of Analyzed ERTS-1 Imagery

Frame Number	Date
1023-16440	August 15, 1972
1041-16435	September 2, 1972
1311-16444	May 30, 1973
1329-16443	June 17, 1973
1347-16441	July 5, 1973
1401-16443	August 28, 1973

Analyses were confined to Clay County in South Dakota.

3.6.3 Data Handling

(a) Transparencies of the ERTS wavelength bands and dates of interest were successively digitized, transmitted to the computer and stored on magnetic tape for analysis. Pattern recognition and K-Class algorithms developed in Section 6.0 of this study were used to analyze the data.

(b) Data from test fields were analyzed using the K-Class classifier for all possible combinations of features to determine which features gave the most satisfactory results. Using the test fields as a training set, the entire study area was classified. Study-area results were later used to extrapolate to classify the entire County.

(c) A pattern recognition algorithm called "mode seeking" was also tested using study area data.

3.6.4 Identification of Crops. After appropriate crop "signatures" and classification procedures were developed using test field data, crops in the entire study area were identified and classified. The machine results were compared with the ground truth as a measure of accuracy.

3.6.5 Land Use in Clay County. A land use map of Clay County which identified major crops and their distribution was prepared. The crop acreage results obtained using ERTS imagery and machine methods were compared with conventional results obtained by the Agricultural Stabilization and Conservation Service.

3.6.6 Soil Influence in Crop Variability. A detailed study of the influence of soil variations on crop "signatures" was accomplished and is reported separately in Section 5.0 of this report.

3.7 SIGNIFICANT RESULTS:

3.7.1 Ground Truth. A base of ground truth information is essential to the success of a machine oriented resource inventory. High altitude aircraft imagery provides a good base map. Ground surveys and low level aircraft photographs are essential for updating base map information. One of the most important uses of the base map was location of field boundaries on digitized imagery.

3.7.2 Data Handling. To reduce the cost of data processing, only the essential portions of images were digitized. Use of ERTS enlargements and the photographically prepared masks were significant aids in preparation of imagery for digitization. Location of field boundaries on computer symbol printouts presented some problem. Limited use of a boundary detection algorithm indicates that significant progress can be made in computer assisted field boundary detection. The nonparametric K-Class classifier appears to be a significant program for crop identification. The mode seeking algorithm did not materially aid in crop identification; however, improvements in the mode seeking capability could give improved results.

3.7.3 Crop "Signature" Results. The histogram signatures for May 30, 1973, and August 28, 1973, are shown in figures 3-2 through 3-9 for ERTS Wavelength bands 4, 5, 6, and 7. Separation of classes was best for single bands 6 and 7.

3.7.4 Clay County Classification Results. The results for land area in Clay County planted to major crops are shown in Tables 3-2 and 3-3. The results obtained using ERTS imagery compare favorably with ASCS figures.

3.7.5 Clay County Land Use. The distribution of crops in Clay County is shown in Figures 3-10 and 3-11.

3.7.6 Band Ratio. The ratio of output codes Band 6/Band 5 was computed for the study area. Although the ratio appeared to enhance bare soil versus dense vegetation, the ratio for the May 30 imagery did not significantly aid crop identification.

3.7.7 Cost of Crop Resource Survey. Assuming that ERTS imagery is available, disregarding development and launching costs, the costs for preparing a land use map for Clay County for one date and one band are:

Machine costs	$147.70
Man-hours 16 at 7.00/hr	112.00
Total	$259.70

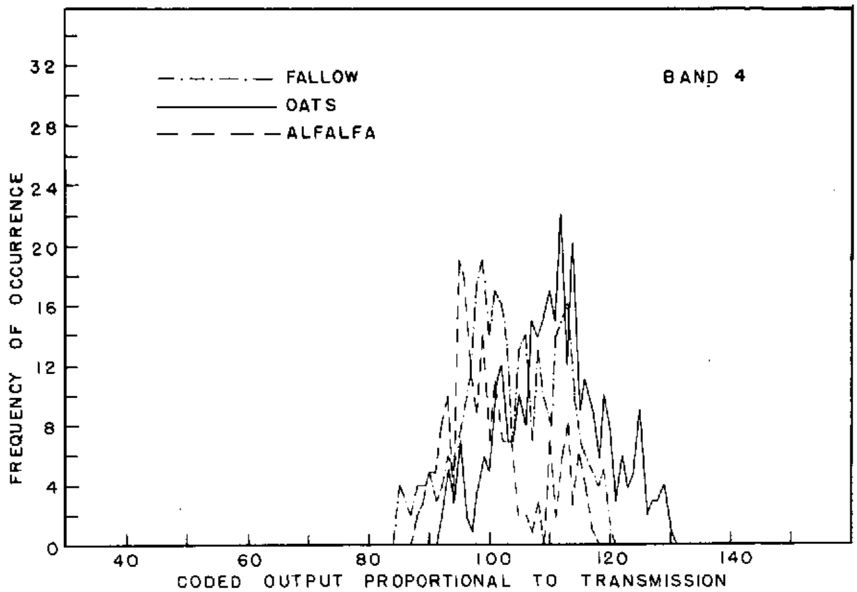


Figure 3-2. Distribution of the May 30 test field data in band 4 (0.5 - 0.6μm).

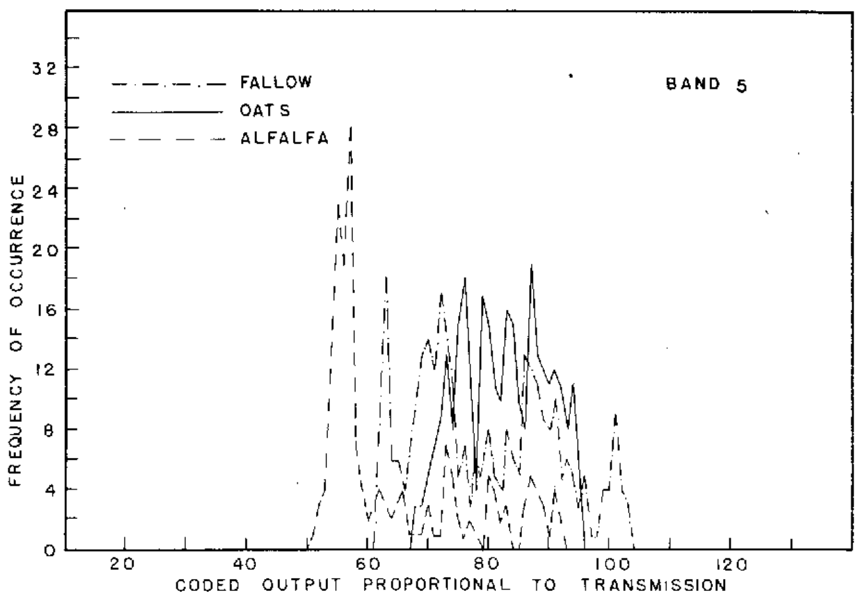


Figure 3-3. Distribution of the May 30 test field data in band 5 (0.6 - 0.7μm).

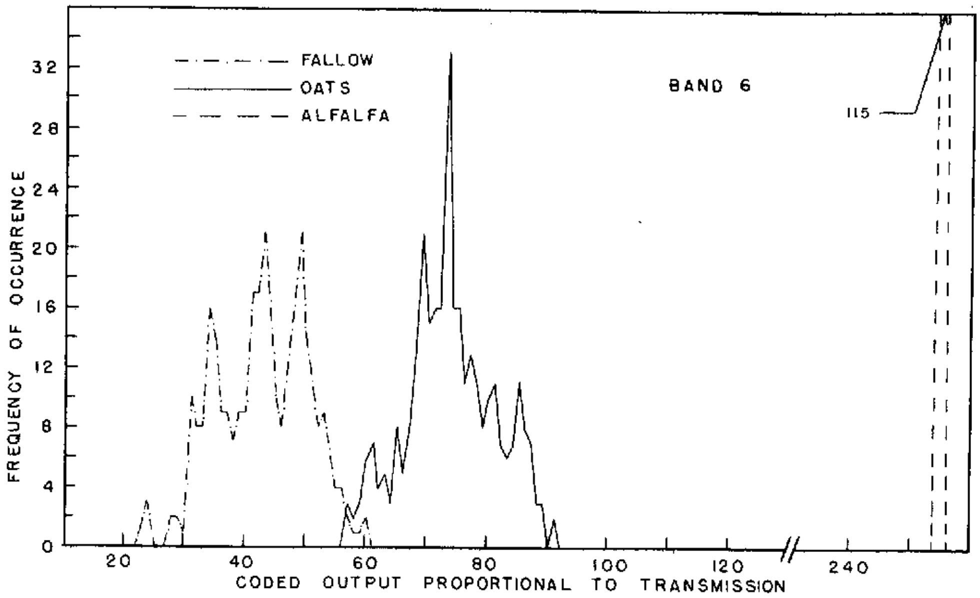


Figure 3-4. Distribution of the May 30 test field data in band 6 (0.7 - 0.8μm).

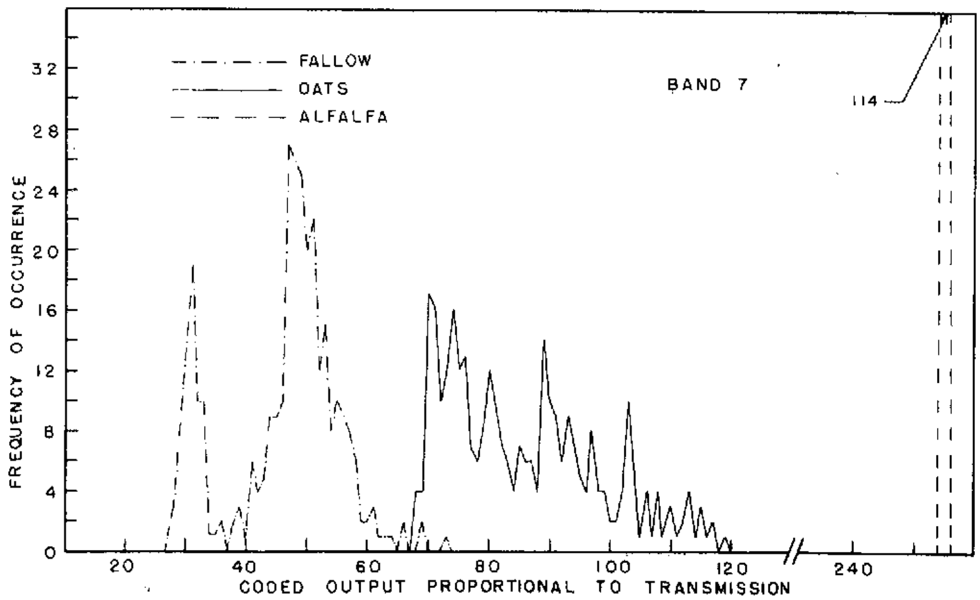


Figure 3-5. Distribution of the May 30 test field data in band 7 (0.8 - 1.1μm).

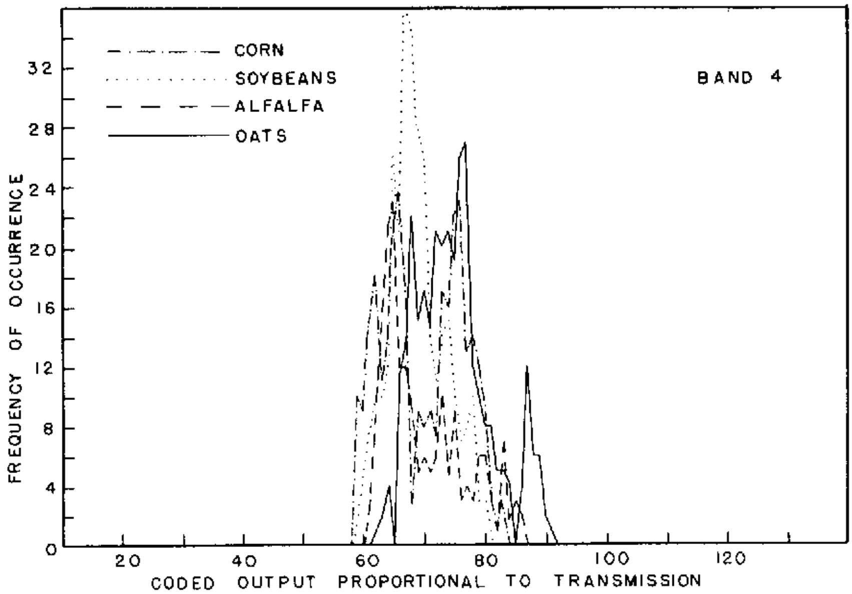


Figure 3-6. Distribution of the August 28 test field data in band 4 (0.5 - 0.6μm).

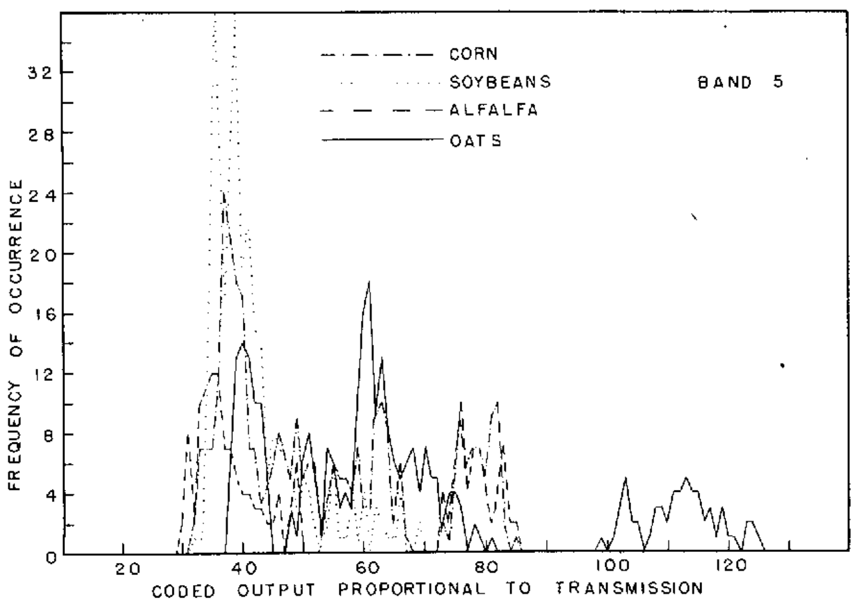


Figure 3-7. Distribution of the August 28 test field data in band 5 (0.6 - 0.7μm).

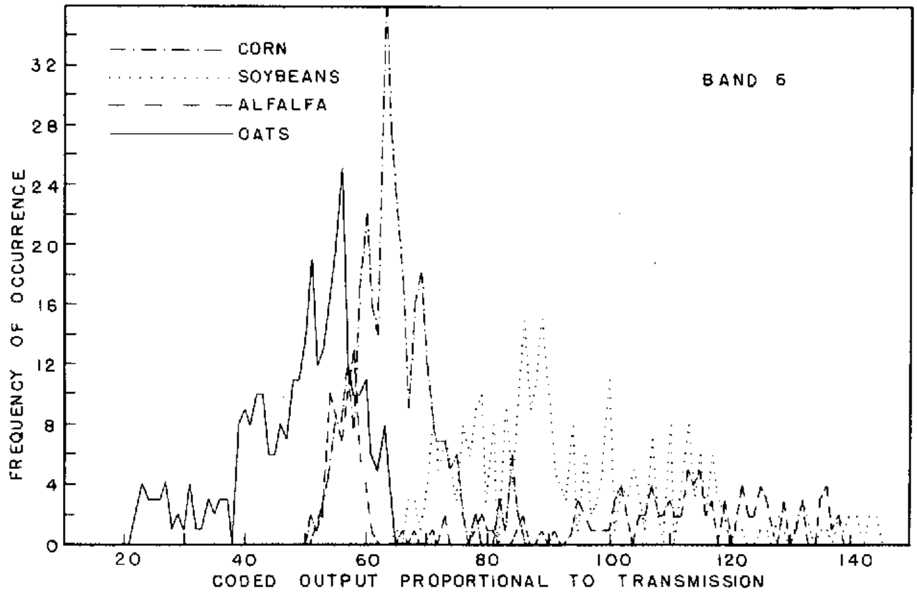


Figure 3-8. Distribution of the August 28 test field data in band 6 (0.7 - 0.8μm).

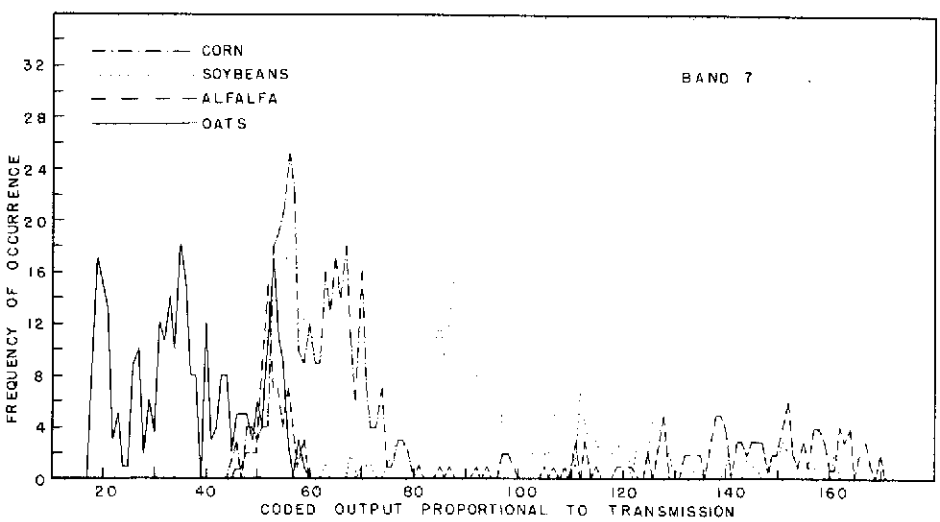


Figure 3-9. Distribution of the August 28 test field data in band 7 (0.8 - 1.1μm).

Table 3-2. Clay County Classification Results for May 30, 1973

Crop	ASCS Figures for 89 Percent of Total Farmland (hectares)	Results Using ERTS (hectares)
Fallow (Corn + Soybeans)	52,707	50,227
Oats	5,465	23,192
Alfalfa	Unknown	4,801

Table 3-3. Clay County Classification Results for August 28, 1973

Crop	ASCS Figures for 89 Percent of Total Farmland (hectares)	Results Using ERTS (hectares)
Corn	36,079	38,849
Soybeans	16,628	20,468
Oats	5,465	9,299

Figure 3-10. A land use map of Clay County prepared from May 30 ERTS information.

White = Fallow (Corn + Soybeans)
Gray = Oats + Alfalfa
Black = Other

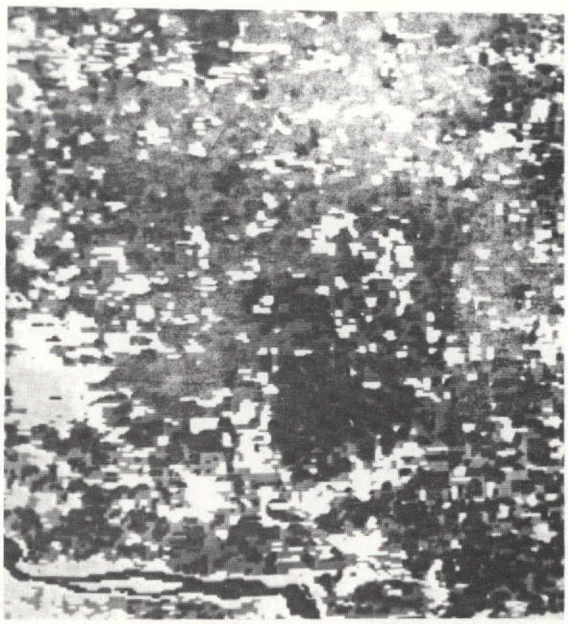


Figure 3-11. A land use map of Clay County prepared from August 28 ERTS information.

Black = Soybeans
Gray = Corn
White = Oats + Other

3.7.8 Use of ERTS in Public Relations The ERTS-1 mosaic of South Dakota described in Section 4.5 was used as a base map with Clay County as the focal point for a public interest display. The crop identification results were used to emphasize the timely regional resource inventory capability of ERTS. The display was prepared for a BiCentennial Planning Meeting and Demonstration for Clay County and the University of South Dakota. Upon completion of this use, the display has been exhibited at the Cornbelt Research and Extension Center located in Clay County.

3.8 SUMMARY AND CONCLUSIONS: The crop identification summary is presented in Table 3-4. Due to the growth characteristics and maturity patterns of field crops, no single data collection period would yield all the needed information. For the crops studied, May and late August imagery was most useful in identification. ERTS data are valuable as a tool in crop resource studies. Machine handling of data is possible for timely regional crop studies, however, development of less expensive data handling techniques is needed for an operational system. Additional research is needed to develop methods that account for soil and stress variables in crop spectral reflectances. Variations in soils, crop varieties, crop management and climate within a region influence the crop radiances viewed from space. ERTS imagery is also valuable as a public relations and educational tool.

4. LAND SYSTEMS: (SOIL ASSOCIATIONS) (DR. F.C. WESTIN)

4.1 INTRODUCTION: Soil maps are an integral part of an effective agricultural research and advisory program. Soil maps are used for farm and ranch planning, crop and grass yield estimates, evaluating land, land use planning, irrigation planning, drainage planning, assessing potentialities for special crops, rural zoning, and for forest management. Soil maps are of different scales ranging usually from 1:15,840 to 1:7,000,000. The large scale maps necessary for detailed land planning show the extent of individual soils, and

Table 3-4. Summary of Study Area Crop Identification

Date	ERTS Bands	Crop Identification Results
August 15, 1972	6, 7	Fallow (bare soil) could be identified because of a lower reflectance than vegetation in bands 6 and 7. Soybeans could not be distinguished from untasseled corn because of reflectance similarities. Tasseled corn and soybeans could be discriminated because tasseling reduced reflectance of corn in bands 6 and 7.
September 2, 1972	6, 7	Fallow could be identified because of a low reflectance in bands 6 and 7. Tasseled corn and soybeans could be discriminated because of reflectance differences due to tasseling.
May 30, 1973	6, 7	Corn and soybeans appeared as bare soil because of high amounts of exposed soil background. Oats, with moderate amounts of exposed soil background, could be distinguished from corn and soybeans in bands 6 and 7 because of a higher reflectance. Alfalfa, with dense, green canopies and low amounts of exposed soil background, had reflectances

Table 3-4. (continued)

Date	ERTS Bands	Crop Identification Results
May 30, 1973	6, 7	which were much higher than corn, soybeans, and oats. Thus, alfalfa was identified.
June 17, 1973	6, 7	Corn and soybeans could be identified because of high amounts of exposed soil background. Oats and alfalfa could not be discriminated because both crops had similar amounts of exposed soil background.
July 5, 1973	6, 7	Soybeans, with moderate amounts of exposed soil background, could not be distinguished from oats that were approaching senescence because of reflectance similarities in bands 6 and 7. Some corn, with lesser amounts of exposed soil background than soybeans, could be identified. Alfalfa was identified because of its low percent of exposed soil background.

Table 3-4. (continued)

Date	ERTS Bands	Crop Identification Results
August 28, 1973	5, 6, 7	Some fields of harvested oats with high amounts of dead vegetation covering the soil surface were identified in band 5 because of a higher reflectance than surrounding surfaces. Fields of harvested oats were identified in bands 6 and 7 because of a low reflectance. Soybeans and tasseled corn could be discriminated in bands 6 and 7 because of tasseling. Alfalfa and soybeans could not be discriminated because both crops had dense, green canopies and low amounts of exposed soil background.

are made by boring holes and walking over the land so that delineations are observed over their entire extent. These soil survey maps are expensive to make and publish. Small scale soil maps, called soil association maps, are geographic associations of one or several soils and usually are at scales of 1:500,000 to 1:1,000,000. Each soil association consists of a set of geographic bodies that are segments of the soil mantle covering the land surface. Soil associations are soil landscapes that occur in repeating patterns. They may contain like or unlike soils but the association itself is homogeneous and different from other soil associations when viewed on the imagery. Field checking of soil association maps is done at infrequent intervals depending upon the scale and use of the map. Although soil association maps of small scale are not as precise for interpretations as detailed soil maps of large scale, they cost much less to make and they do have use for broad planning purposes and for education. It should be emphasized that the soils shown on soil maps are not defined in terms of profiles alone. Each soil unit is a particular kind of landscape and it is these landscapes of soils that are classified and shown on soil association maps. Although soil profiles cannot be seen on air or satellite imagery, soil landscapes are visible. In this regard it should be stated that soil survey experience is necessary if maximum use is to be made of ERTS-1 MSS imagery for identifying soil associations. Soil landscapes exhibit a characteristic surface geometry such as relative frequency of streams, and a characteristic surface composition such as the percentage of bare soil areas. Other features used in differentiating soil landscapes include vegetation and hydrology. These usually show up as tone differences. Five factors control the formation and distribution of soils and soil associations. These are: climate, organisms (dominantly native vegetation), soil parent material, topography and time. With the exception of time, these factors define the environment of soil formation. Time gives the total potential for change, and is not considered in this study as a separate factor resulting in recognizable boundaries. Climate and native vegetation are closely related and usually are considered together since both are dynamic factors acting upon soil parent materials on different topographic sites.

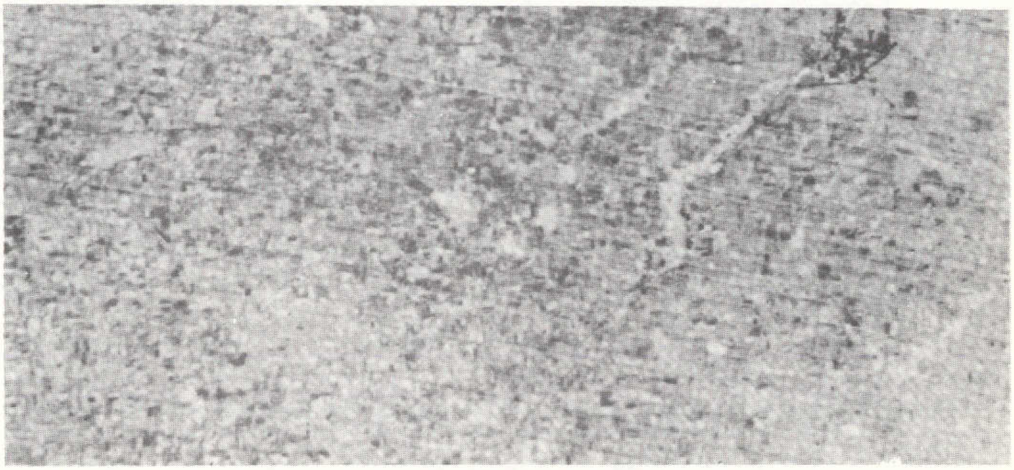
4.2 OBJECTIVE: The specific objective of this study was the recognition of soil association boundaries on ERTS-1 images and mosaics and the publication of soil association maps on ERTS-1 imagery.

4.3 PROCEDURE: The ERTS data used for this study consisted of 9-inch transparencies, color composites, 70 mm chips, color enlargements and computer compatible tapes. Enlargements up to a scale of 1:60,000 were made of some of the imagery. In this study, an effort was made to study ERTS-1 imagery using equipment usually available to a soil survey office. This consists mainly of access to a dark-room with a good enlarger having a non-diffuse light source. A diffuse light enlarger tends to blend and smooth out boundaries on the images which is not desired for photo interpretation purposes.

4.4 ACCOMPLISHMENTS:

4.4.1 Recognition of Soil Boundaries due to Climate and Vegetation. Soil profiles cannot be seen on either air or satellite imagery and, for a large part of the growing season each year, even the surface soil of South Dakota is covered with vegetation. Thus, recognition of soil association boundaries must be inferred, in part, from the patterns made by the present vegetation since this is the principal way that climate and native vegetation are expressed. Soil association boundaries separate kinds of agriculture. For example, corn and soybeans are grown in South Dakota in the eastern and southeastern part where the soils have developed under a warm-moist climate and tall grass vegetation. Moving northwest, spring wheat takes over as the main crop. Spring wheat is at its peak of green growth in June at which time corn is just beginning to mantle the soil. Thus, band 7 of May ERTS passes will show high reflectance where spring wheat is the dominant crop. On August imagery the corn and the soil associations used for spring wheat will have low reflectance. Thus, both the temporal and multispectral characteristics of ERTS imagery are utilized in recognizing boundaries of soil associations. Other characteristics used include field size (larger in wheat area) and percentage of the soils in pasture or range grass (larger in wheat area). Some role in soil formation is played by both precipitation and temperature. Precipitation affects the amount of water that enters the soil and hence the chemical and physical weathering processes, eluviation and ion movement. Moisture relationships also affect the amount of residues that are returned to the soil and the speed of their decomposition. Temperature controls the heat available for the physical, chemical and biological processes of soil formation. Weathering generally increases with an increase in temperature if moisture is not limiting. Also, higher temperatures generally increase the rate of organic matter decay. The general characteristics of soils can be related to climate. Although there are many interrelationships, the most significant ones generally relate to a single soil property such as organic matter content and a single climatic component like precipitation. The climate in South Dakota is subhumid in the eastern part and semiarid in the central and western parts. Tall grass prairie was the principal vegetation in the subhumid east while mid and short grasses were the native vegetation types in the semiarid central and western parts. The principal biotic factor in soil formation is vegetation since it is the major source of organic matter. The effect of vegetation on soil properties differes with the kind of vegetation. Grasses contribute large amounts of organic matter that darken the upper layer of soil. The intensity of the development of these upper horizons correlates well with the climate resulting in darker and thicker dark colored horizons in eastern South Dakota and gradually thinning and becoming lighter colored in moving to the northwest corner. Since climate is a continuum, the soil thickness and darkness also are a continuum. As long as soil parent material and topography are constant factors, the soil boundaries related to climate and native vegetation are gradual. Thus, the problem of delineating soil boundaries which are due to climate has been difficult by conventional means since no one aerial photograph or county mosaic covered sufficient area to see evidence of soil differences that could be attributed to climate and vegetation. ERTS scenes cover larger areas, however, and this synoptic view provides an opportunity to observe soil associations and their use over an area of climatic change. As mentioned, however, climatic change is gradual and as long as soil parent material and topography remain constant, the soil association boundaries that result from climatic change are gradual. Fortunately, however, there often is a topographic or soil parent material change which provides a distinct boundary and the climatic continuum can be partitioned in this manner. Figures 4-1 and 4-2 illustrate this point. Figure 4-1 is of Western Minnesota along latitude 44° 15'. The climate gradually is becoming drier from east to west. This is seen in the gradual darkening of the tone of the MSS-7 negative of spring grain which is near its peak of green growth on 17 June. The more humid eastern area is planted to corn and soybeans, neither one of which has produced much vegetation by this date. Three soil parent material boundaries occur on the scene at roughly right angles to the climatic change. These soil parent material boundaries then serve also to partition the climatic continuum. Figure 4-2 is from east-central South Dakota. Here, also, the climate gradually is becoming drier from east to west, and this is seen on the MSS-7 negative print as a gradual darkening

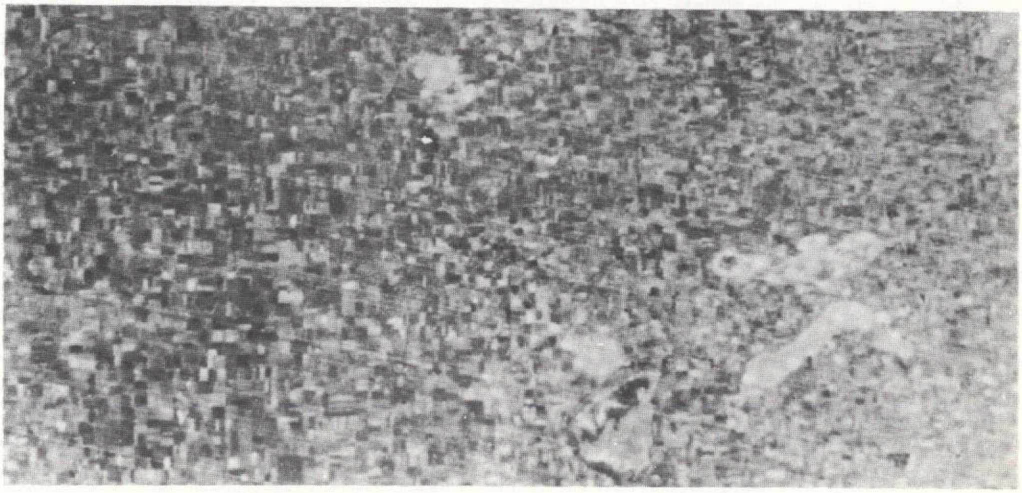
MSS-7



MSS-5

Figure 4-1. Use of ERTS-1 to detect Soil Association boundaries due to climatic differences, Western Minnesota 17 June '73, negative prints, Scale 1:500,000.
Along 44^{o} latitude precipitation decreases in western Minnesota as the South Dakota state line is approached, and this fact is recognized by farmers who increase the proportion of small grain (a crop requiring less moisture) relative to corn and soybeans. On MSS-7 of this negative print from 17 June imagery, the lighter tones are on the more humid east, where most of the land has been planted to corn or soybeans about a month earlier. These crops have not yet mantled the soil so a large part of the reflectance on MSS-7 is of the soil. Moving west the number of fields in small grain (which is at its peak of green growth on 17 June and thus reflects strongly on MSS-7) increase, gradually increasing the proportion of dark tones on MSS-7. MSS-5 does not show these tonal differences.

MSS-7

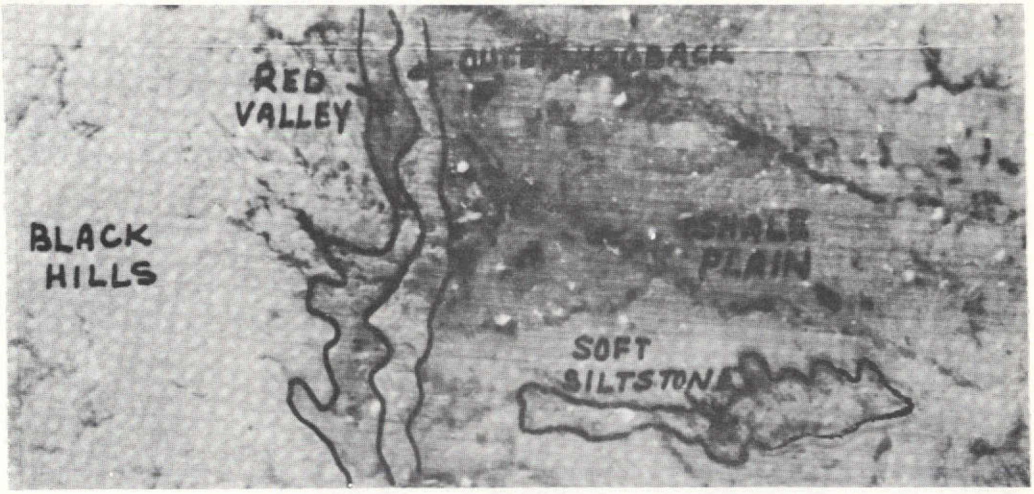


MSS-5

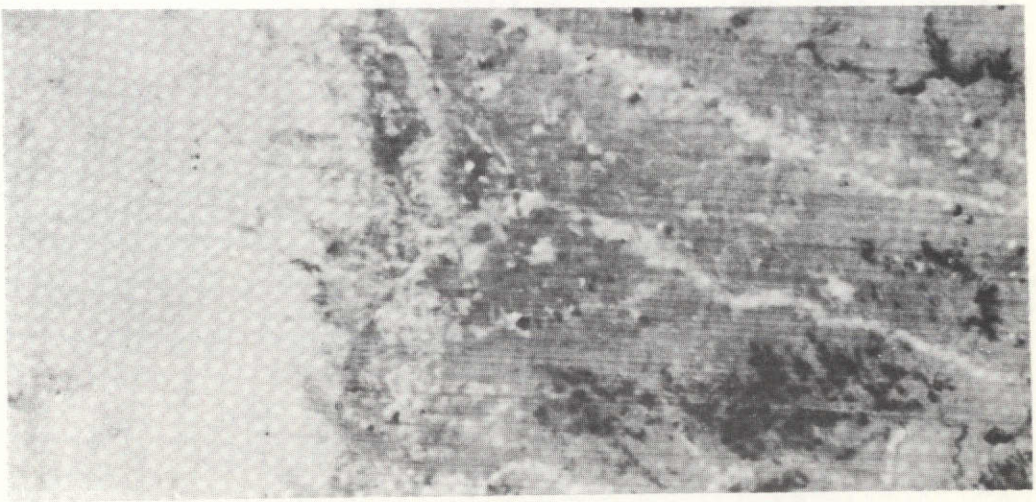
Figure 4-2. Use of ERTS-1 to detect Soil Association boundaries due to climatic differences, Dry subhumid and moist subhumid climates, glacial soils.
In this May 16, 1973 ERTS scene, the moist subhumid Prairie Coteau (Udic soil subgroups) on the east has a higher proportion of corn and soybeans than the dry subhumid James Valley (Typic soil subgroups) which is primarily in spring grain and grass. Since the spring grain and grass are near their peak of green growth on this date, they have higher reflectance on band 7 than the Prairie Coteau which has a smaller mass of vegetation and hence has a comparatively low reflectance. This climatic boundary is apparent on MSS-7 but not MSS-5. Scenes taken in August also will show this but the reflectances on band 7 will be reversed from that shown on the May scene.

of the tone of less corn. This ERTS scene is of 16 May when corn is in the process of being planted and thus the corn land reflects very light gray on the negative print of MSS-7 while the wheat, which is present in larger proportion on the west, has a dark tone. The light tones signifying corn land are present in larger proportion on the east part of the figure. Crossing at nearly right angles to this climatic change is a soil parent material change which then also serves as a boundary for a climatic change.

4.4.2 Recognition of Soil Association Boundaries Caused by Soil Parent Materials: Soil parent materials may be classified into one of three groups: residual, transported and organic. Since organic materials are not present in soil associations in South Dakota they are not discussed further here. Residual soil parent materials include hard igneous and metamorphic rocks, as well as hard and soft sedimentary rocks. The hard rocks weather very slowly to produce thin soils. In South Dakota these occur in the Black Hills and are further distinguished by rugged mountainous relief. These areas of different rocks have sharp boundaries visible on MSS-5 and 7 of ERTS (see figure 4-3). They have greater reflectance differences with surrounding areas on band 5 than the other bands. Softer sedimentary rocks include sandstones, limestones and shales. These along with alluvium and loess characterize the west half of South Dakota. Soil association boundaries caused by a change in the soft sedimentary rocks are sharp in South Dakota, and are visible on ERTS images in any season on bands 5, 6, and 7 or on color composites. Several kinds of soft sedimentary rock soil parent material are shown on figures 4-4 and 4-5. The Sand Hills consist of unconsolidated deep coarse sands on undulating or hummocky relief used for range grasses. The Pine Ridge

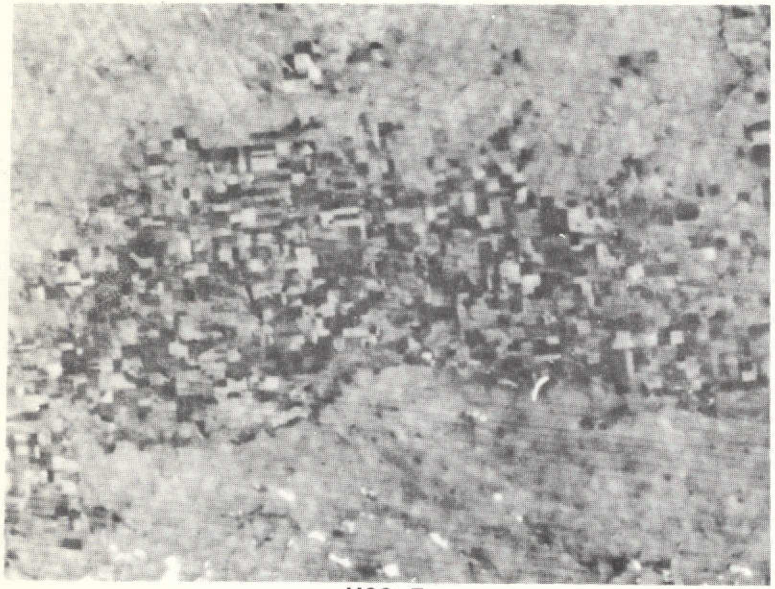


MSS-7

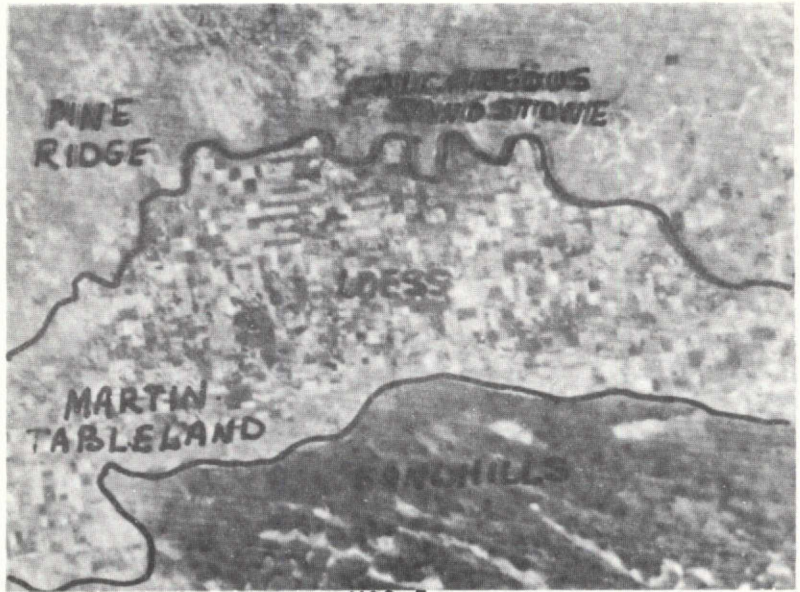


MSS-5

Figure 4-3. Use of ERTS-1 to detect Soil Association boundaries due to soil parent material differences, Limestone, Sandstone, Shale, Siltstone, Western South Dakota, negative prints, Scale 1:500,000.
On this May 6, 1973 scene, the Black Hills area shown is developed from a hard limestone and is mantled with coniferous vegetation; the Red Valley is from a soft shale and is in grass; the Outer Hogback is from a hard sandstone and is partly in grass, partly in trees; the soft shale plain is in grass; and the light-colored soft siltstone area is barren badlands. The boundaries of each of these soil parent materials are apparent on both MSS-5 and 7 of ERTS but the contrast among these materials is more pronounced on MSS-5 than on 7.

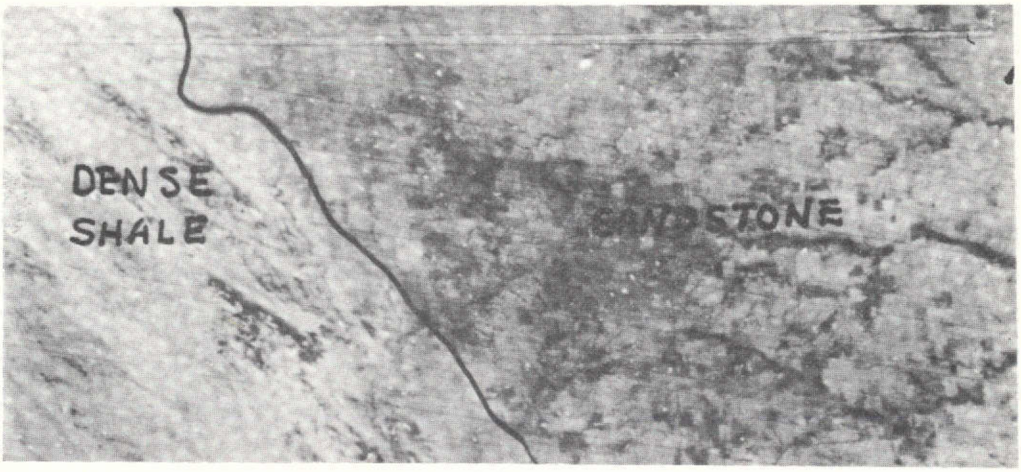


MSS-7



MSS-5

Figure 4-4. Use of ERTS-1 to detect Soil Association boundaries due to soil parent material differences, Sandhills, Loess, Sandstone (Semiarid climate), Southwestern South Dakota, negative prints, Scale 1:500,000.
On this May 1973 scene, the boundaries separating sandhills, loess and sandstone are readily apparent on both MSS-5 and 7, however, the gray tones denoting reflective differences are most apparent on MSS-5. Both the Sandhills, and the Pine Ridge are in grass but the latter has a well developed network of streams denoting low soil infiltration rates due to steep topography or slowly permeable soils or both. The nearly white fringe area along the drains is due to the low reflectance of the Pine trees and is seen best in MSS-5. The Sandhills has no drainage network indicating a high infiltration rate as would be expected on a sandy soil. The loess area is characterized by a field pattern of fallow (light gray on MSS-7) winter wheat (dark gray on MSS-7) and milo (also light gray on MSS-7). In the semiarid climate characterizing this area, only the most favorable soils are cropped. Conversely, since the income from wheat and milo is higher than from grass, few favorable soils are not cropped; thus, in this area land use correlates with soil quality.

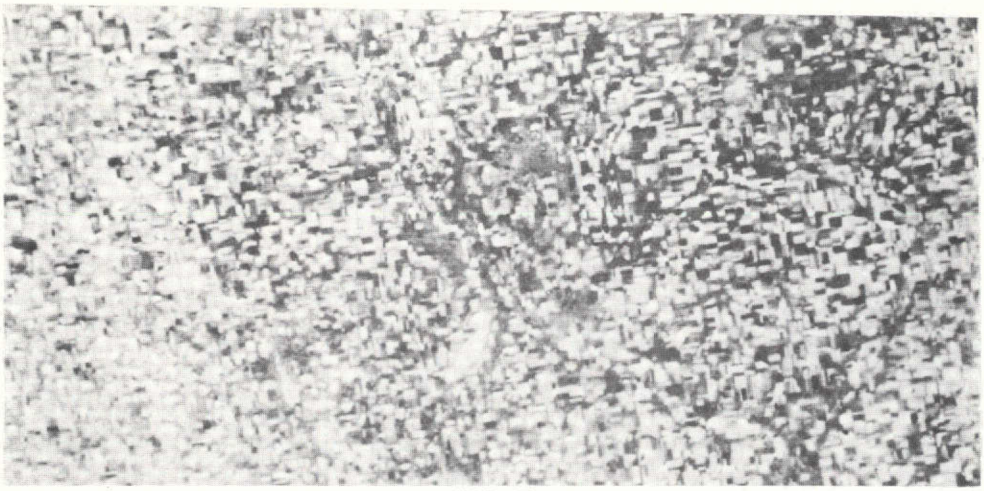


MSS-7

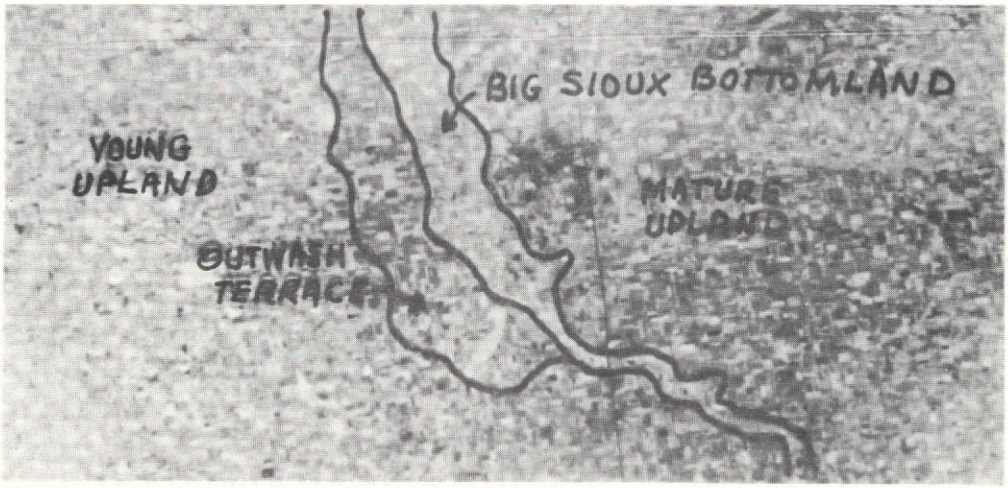
MSS-5

Figure 4-5. Use of ERTS-1 to detect Soil Association boundaries due to soil parent material differences, Dense Shale and Sandstone, Semiarid Climate, Western South Dakota, negative prints, Scale 1:500,000.
On this May 15, 1974 scene, the dense shale soil area is nearly barren of vegetation while the sandstone areas has a modest cover of cool season grasses and an occasional field. On band 7 the dense shale-derived Winler soil area has very low reflectance appearing nearly white on the print. Tonal differences between these two soil parent materials is not as pronounced on band 5.

is from a partially cemented calcareous sandstone and the soils here are generally shallow sandy loams on steep, north-facing slopes. This environment is suited for range grasses and Ponderosa Pine. The pine grows generally on the steepest valley sides and its reflectance is much lower on band 5 than is the grass. Thus on this band there is a unique veining pattern following the location of the Ponderosa Pine. The siltstone in this area is high in calcium carbonate and is light tan to white in color. The soils that develop are thin, especially on the slope breaks and knobs and the whitish parent material gives a high reflectance on band 5 of ERTS. The siltstone area erodes to barren badlands where a slope differential or wall occurs but otherwise is used mainly for growing range grasses and occasionally a field of winter wheat. The appearance of the siltstone area on ERTS imagery then is one of uneven tone caused by the association of moderately deep and shallow soils and the boundaries separating the area from the adjacent soil associations is sharp. The shale in this area is a rather dense, very fine-textured marine deposit and the relief on which it occurs is rolling. The fine textures and strong relief result in high runoff so the production of grass (which is the main use) is low. Thus the IR reflectance generally of these areas is low. The high runoff from these clay materials is carried from the uplands mainly by a fine network of closely spaced streams. This stream network and the low IR reflectance are two features identifying the shale soil parent materials. The boundary separating shale from associated soil parent materials in this area usually is sharp and is visible on the ERTS images, especially on band 7. Figure 4-5 shows the delineation of soil association boundaries between a dense shale and a sandstone. Transported soil parent materials usually are named to show the principal agency responsible for transportation and deposition. A common feature of transported soil parent materials is that they occur in an unconsolidated state, thus they give rise to deeper soils generally than do residual materials. The transported soil parent materials can be subdivided into deposits from running water, glacial deposits, and wind-laid sediments. Running water deposits include alluvium and terrace materials. For major rivers, boundaries of both deposits can be distinguished on ERTS images. Alluvial deposits are identified by stream proximity, linear shape and usually by having a network of drains. In addition, the valley floor and bluff usually have a sharp boundary caused by reflective differences of the valley floor vegetation and the sparser vegetation of the steep valley sides. Figure 4-6 shows the delineation of the Big Sioux River bottomland and a terrace near Brookings, South Dakota. Terrace soil parent materials also occur near streams, but back from the alluvial plain. They also usually have linear shapes but lack a network of drains since they are above the level of flooding. Since they occur on flat topography and the materials are friable, the soils usually are among the most productive for their area of occurrence and are under cultivation. Thus a field pattern of cropland with few, if any, areas of grass or trees further characterizes terraces in South Dakota. Since these soils are the most productive in their area, the total biomass produced is larger than surrounding areas and terraces have higher reflectance on band 7 than adjacent areas. Glacial soil parent materials in South Dakota include till and outwash. Till is generally medium textured and is deposited in undulating ground moraines and steep end moraines. Glacial outwash, which is coarse textured, is carried by water beyond the ice front onto a plain. Glacial till soil parent materials on undulating or nearly level slopes and outwash plains generally are under cultivation and so have a pattern of field boundaries. Steeply sloping or hilly



MSS-7



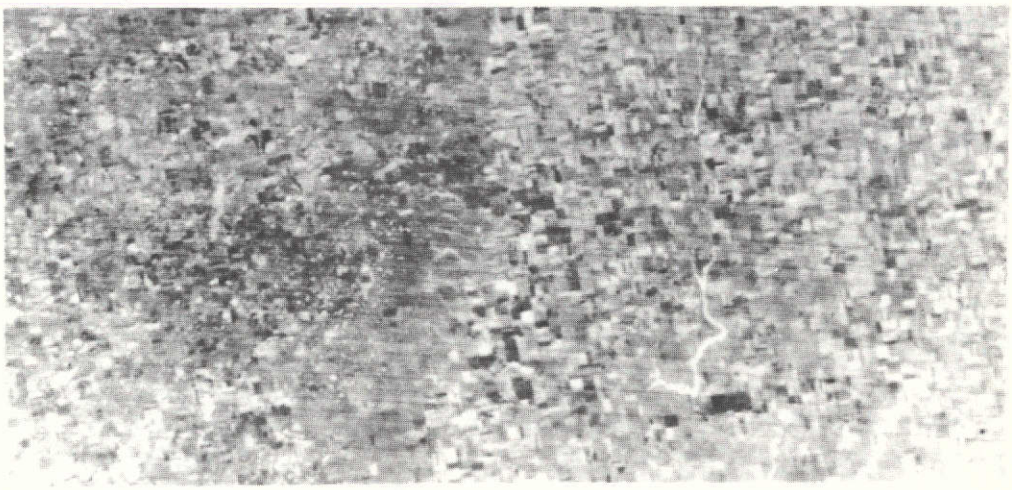
MSS-5

Figure 4-6. Use of ERTS-1 to detect Soil Association boundaries due to soil parent material and land form differences, Bottomland, Terrace and Upland, Eastern South Dakota, negative prints, Scale 1:500,000.

On this 17 June 1973 scene the boundaries of a bottomland, an outwash terrace, and two glacial uplands are apparent on MSS-5. The distinguishing features include reflective differences shown in gray tones, regularity of field patterns, presence or absence of streams, presence or absence of lakes and marshes. The last named feature is also seen on MSS-7. The reflective differences apparent between the poorly drained bottomland and the well drained terrace are due to the high incidence of grass vegetation on the bottomland which is near the peak of growth on 17 June. The higher lying terrace has well drained soils and is used exclusively as cropland. The west-lying glacial upland is dotted with marshes and lakes while the east-lying glacial upland has no lakes but instead has a stream drainage network.

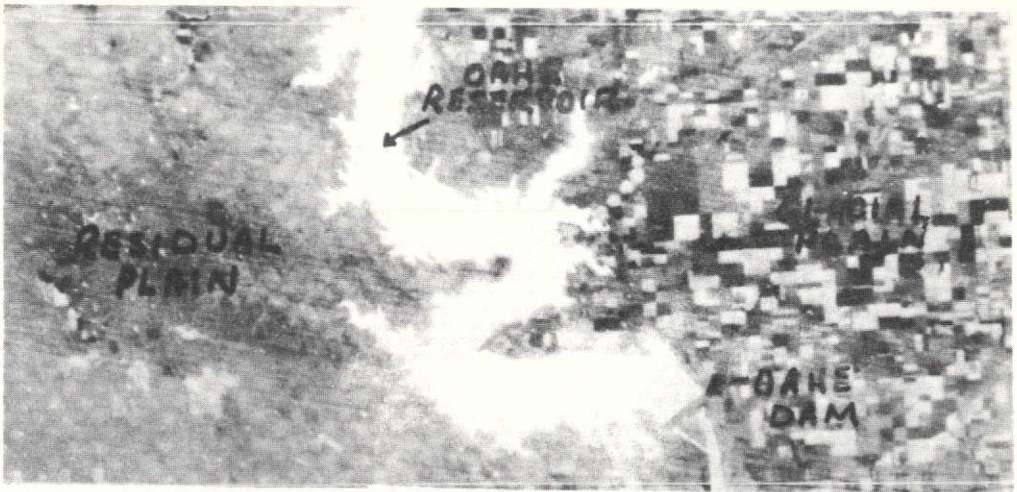
glacial soil parent materials generally are in grass or trees, thus land use is useful in the separation of these two kinds of glacial till soil parent material. Figure 4-7 illustrates the distinct boundaries on MSS-7 imagery that separate a dead ice moraine, and end moraine, and ground moraine in north central South Dakota. Each of these is a soil association area. In general, boundaries separating glacial soil parent materials can be distinguished from residual soil parent materials on ERTS. The residual soil parent materials are on an erosional landscape consisting of broad ridge tops, valley sides and well defined stream courses. The glacial landscape is one where the land forms have been constructed by glaciers. It consists of broad plains interrupted by hilly ridges. The stream drainage pattern is less well defined and often the glacial plain is dotted with morainic depressions, marshes and lakes. See figure 4-8. Boundaries separating mature glacial plains can further be distinguished from immature glacial plains in that the former has a well developed network of streams and the latter is characterized by poorly drained areas and no stream surface drainage network. See figure 4-7. Band 7 is superior for boundary detection in glacial areas since all water bodies are clearly shown. The wind-deposited soil parent materials in South Dakota include loess which is silt size, and eolian sand. Loess deposits are superior soil parent materials since they are friable and permeable. Thus they are cultivated for the most part even in semiarid climates. Figure 4-9 is an ERTS image from southeast South Dakota. Here a thick loess occurs on a rolling upland which dictates use of a high percentage of close-growing crops like small grain to help control water erosion. On June imagery, these crops are near their peak of green growth and thus reflect strongly on MSS-7. The flat areas are used for corn and soybeans primarily and these

MSS-7

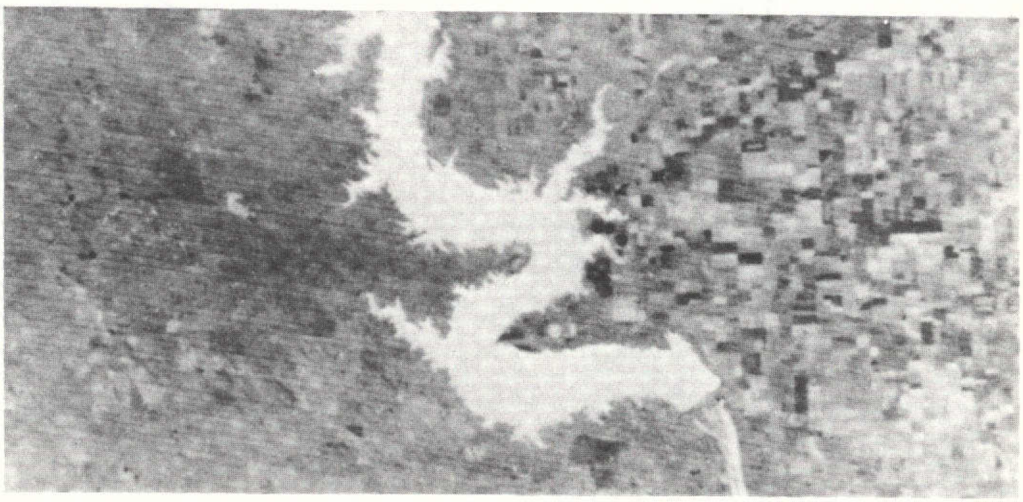


MSS-5

Figure 4-7. Use of ERTS-1 to identify Soil Association boundaries due to soil parent material differences, Dead-Ice Glacial Moraine, End Moraine, Ground Moraine, North-central South Dakota, negative prints, Scale 1:500,000. On this 1 June 1973 scene the boundaries separating three kinds of soil parent materials are distinct on both MSS-7 and 5. The slight haze present however, was not penetrated as well by the MSS-5 as by the MSS-7 wavelengths resulting in a sharper image for the latter. The distinctness of the boundaries separating these soil parent materials is due to 1) unique land and water patterns of the strongly undulating Dead-Ice area seen especially well on MSS-7; 2) the uniform gray band of the steep, stony end moraine; and 3) the regular field pattern almost uninterrupted by lakes or grassed areas of the ground moraine.

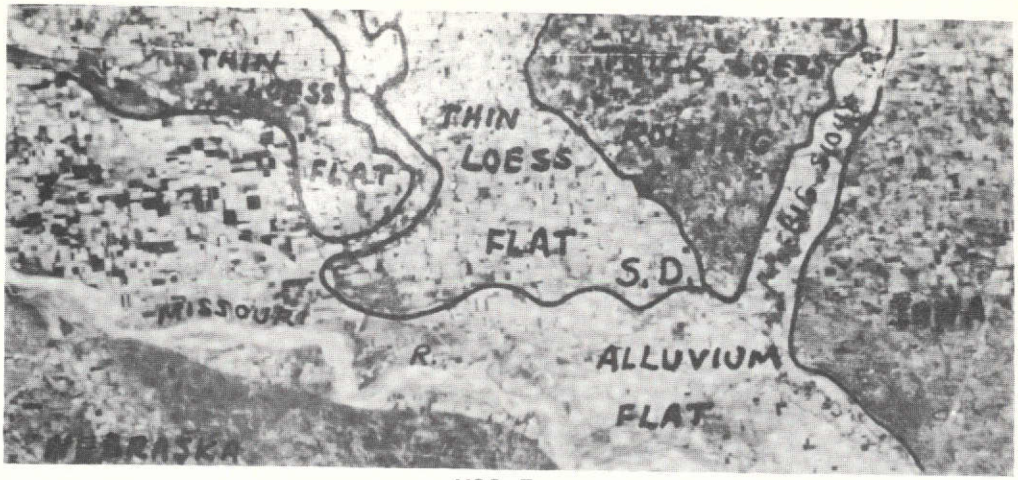


MSS-7

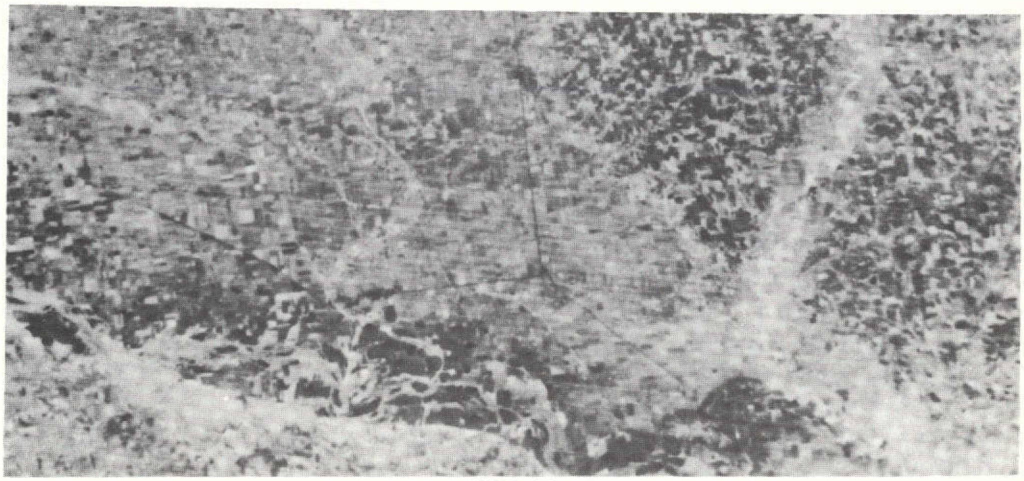


MSS-5

Figure 4-8. Use of ERTS-1 to distinguish Soil Association boundaries due to soil parent materials, Residual and Glacial Soil Association-Landscapes, Central South Dakota, negative prints, 15 May '73, Scale 1:500,000.
The Oahe reservoir in central South Dakota occupies the trench of the Missouri River. East of this trench are friable medium textured glacial soil parent materials on a gently undulating surface having morainic depressions, marshes and lakes. West of the trench are firm clayey soil parent materials on a rolling surface characterized by broad ridges, steep valley sides and stream courses. The clayey residual soils on strong slopes are used primarily for rangeland, while the friable medium textured soils on gently undulating surfaces are mostly cropped to winter and spring wheat and corn.



MSS-7

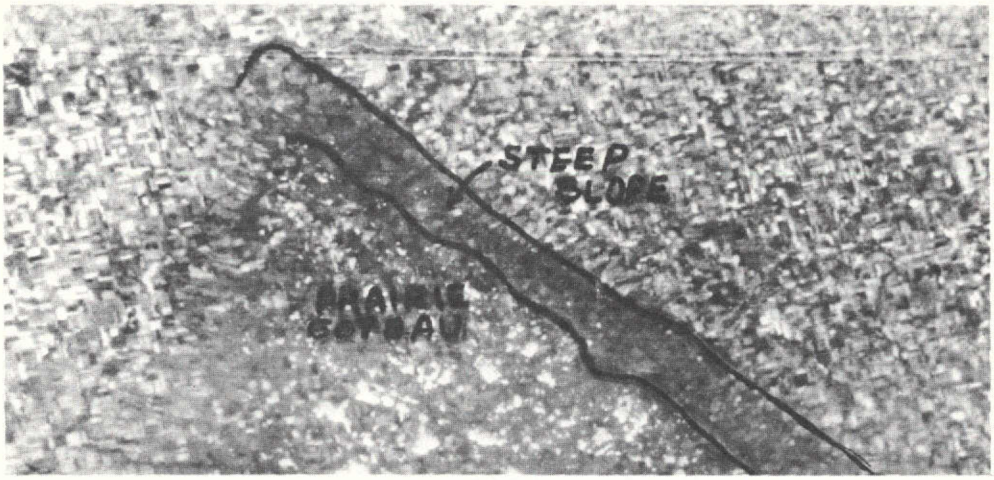


MSS-5

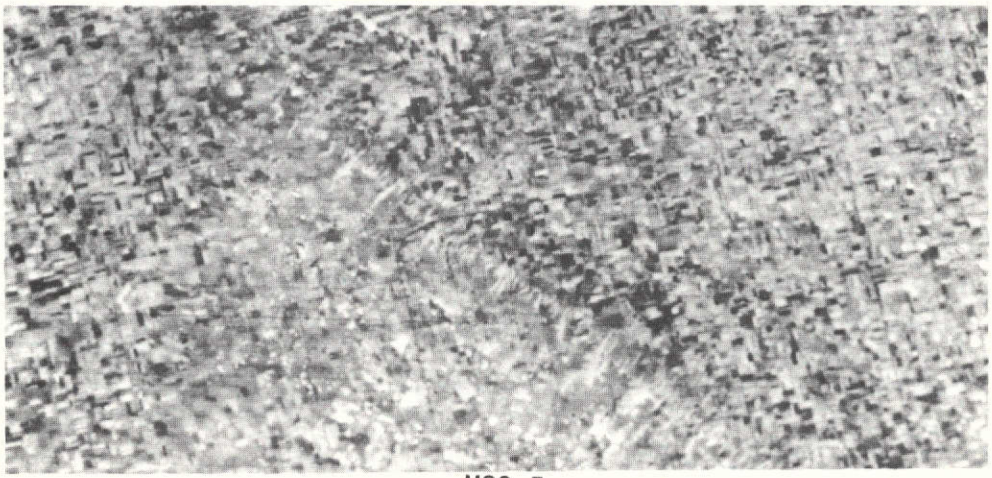
Figure 4-9. Use of ERTS-1 to identify Soil Association boundaries due to soil parent material differences, Loess and Alluvium, Southeast South Dakota, negative prints, Scale 1:500,000. On this 17 June 1973 scene boundaries between two loess areas are apparent on both MSS-5 and 7. In addition, the alluvial area boundaries are distinct on MSS-7 from the thick loess area having rolling relief. The thin loess area having flat relief and the alluvial plain have similar reflectances. The agricultural land use in southeast South Dakota consist of raising corn and soybeans and some alfalfa and small grains on flat or nearly level soils while close-growing crops like small grains dominate steeper slopes. On 17 June the small grains are near their peak of vegetative growth thus reflecting strongly on MSS-7 while the flats having more corn and soybeans have soil exposed over much of the area (as these crops were planted only about a month earlier) and have low reflectance. An August scene would show reverse reflectance as the areas having more corn and soybeans would give higher reflectance than the associations with more small grain.

crops have not grown sufficiently by mid June to give much reflectance on MSS-7. Therefore, these areas have light tones on the negative prints of figure 4-9. Field patterns often indicate loess soil parent materials in western South Dakota. See figure 4-4. The boundaries separating loess from eolian sand and residual sandstone are sharp as is shown in the figure. Eolian sand soil parent materials also have sharp boundaries with loess and sandstone. The identification keys for eolian sand soil parent materials are that the areas are in grass (because of the severe wind erosion hazard), they lack any surface streams and their general configuration is one of hummocks and ridges interspersed with small flats, dips and depressions. The boundaries delineating eolian sand soil parent material are distinct on ERTS images.

4.4.3 Recognition of Soil Association Boundaries Caused by Topography. Topography affects soil formation mostly by modifying the climate. Precipitation effectiveness is influenced by runoff which is controlled by topography. Likewise the slope aspect and degree of slope affect the amount of solar radiation received which in turn affects soil temperature and evaporation. Thus the climatic environment induced by topography affects the vegetation and the boundaries delineating this climatic effect can be observed on ERTS images. This is shown on figure 4-10 where the steep slope of the Prairie Coteau appears as a wide, dark area on MSS-7 while it is not apparent on MSS-5. The evidence of steep slopes along valley sides can also be inferred from the close spacing of drains, into a river valley as is shown in figure 4-11. Here the evidence is apparent on both bands 5 and 7. Differences in soil moisture regimes influenced by topography are significant. In the sandhills the low lying basins receive runoff and have poorly drained soils high in organic matter. Although small basins usually are not individually separated on soil association maps, their presence or

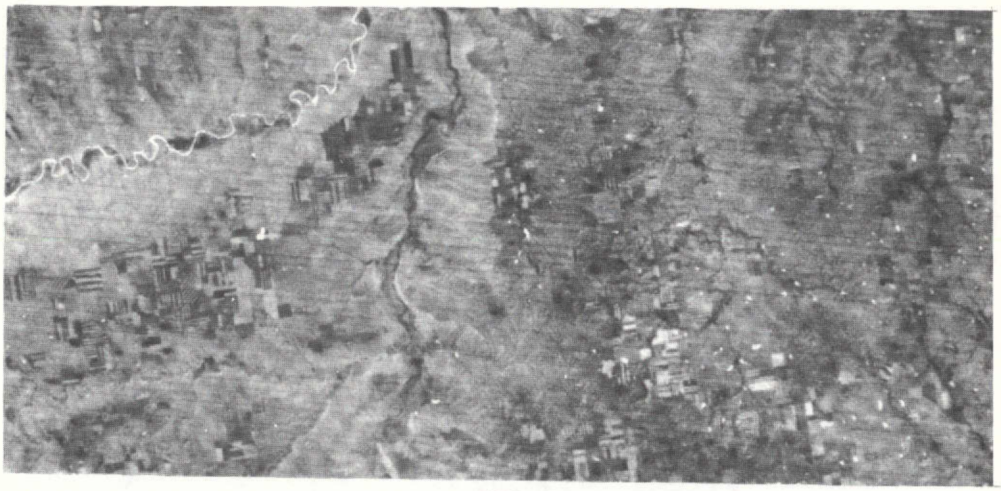


MSS-7

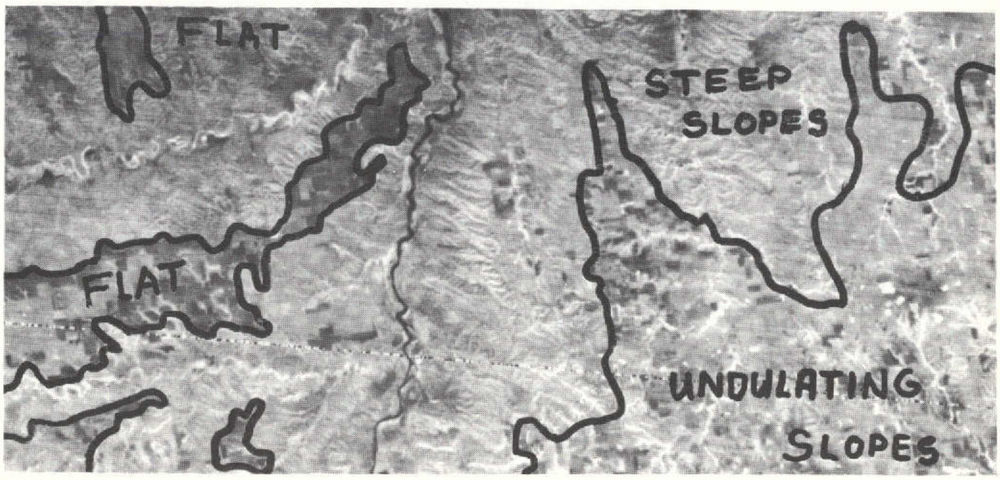


MSS-5

Figure 4-10. Use of ERTS-1 to distinguish Soil Association boundaries due to topography, Glacial Area, Eastern South Dakota, negative prints, Scale 1:500,000.
On these July '72 prints the steep escarpment of the Prairie Coteau stands out on MSS-7 as a broad dark band with distinct boundaries. This area is in grass because of its rugged topography and stoniness. On 29 July this grass is growing vigorously and hence reflects highly on MSS-7. On the Coteau lighter tones are prominent accentuated by many lakes on the crest of the Coteau. The lower-lying areas east and west of the Prairie Coteau have a field pattern indicating intensive cultivation. The light-toned fields shown on MSS-7 in this area have recently been planted to corn which has not grown enough at this time to have much reflectance on MSS-7. The steep slope is marked on MSS-5 by closely spaced parallel drains.



MSS-7



MSS-5

Figure 4-11. Use of ERTS-1 to recognize Soil Association boundaries due to topography, Residual Area, Western South Dakota, negative prints, Scale 1:500,000.
On these 9 July 1973 prints the steep valley sides of the Cheyenne and Belle Fourche rivers stand out with distinct boundaries on both MSS-5 and 7 from the adjacent less sloping areas. These steep areas, exclusively in grass, have thin clay soils derived from shale and produce less vegetation than the deeper, more friable soils occurring on less steep topography. Thus they have a reflective difference apparent on MSS-7 and this reflective difference correlates with the topographic boundary. On MSS-5 the reflective difference between the steep and less steep areas is less pronounced but the closely spaced stream network of the valley sides is more sharply etched, thus both MSS-5 and 7 aid in distinguishing the steep valley side boundaries.

absence is a characteristic of the soil association, and hence being able to see their boundaries on ERTS is significant. Upland and lowland is a broad topographic classification of soil associations. Lowlands include alluvium and terrace soils which usually have well defined boundaries visible on ERTS. Upland soils on undulating topography generally are described as mature since they reflect the normal expression of the climate of the area. On steep slopes, thin profiles generally erode as fast as new soil develops. These thin soils produce less vegetation than the associated normal soils for two reasons -- they are thinner and less well supplied with nutrients and they receive less effective moisture for plant growth. Thus the MSS-7 is the most useful to distinguish the boundaries of these thin, steeply sloping soils. This is shown on figures 4-10 and 4-11.

4.4.4 The Relationship Among the Soil Forming Factors. Variation in any of the factors of soil formation can change the soil association. Often the factors interact and the effect is additive or one may nullify another. In figures 4-1 and 4-2, a climatic change is apparant from east to west as corn acreage decreases and spring wheat acreage increases. The climatic boundary is gradual but distinct topographic or soil parent material boundaries occur. Thus a topographic or a soil parent material boundary also serves to divide the climatic continuum. Soil parent material and topography usually change abruptly and these changes produce boundaries visible on ERTS. Because of the reflective contrasts produced on MSS-7 by vegetative differences, the seasonal greening of vegetation coupled with crop calendar information provides a good tool to distinguish soil association boundaries. This temporal advantage coupled with the multispectral advantages make ERTS a valuable tool in distinguishing soil associations.

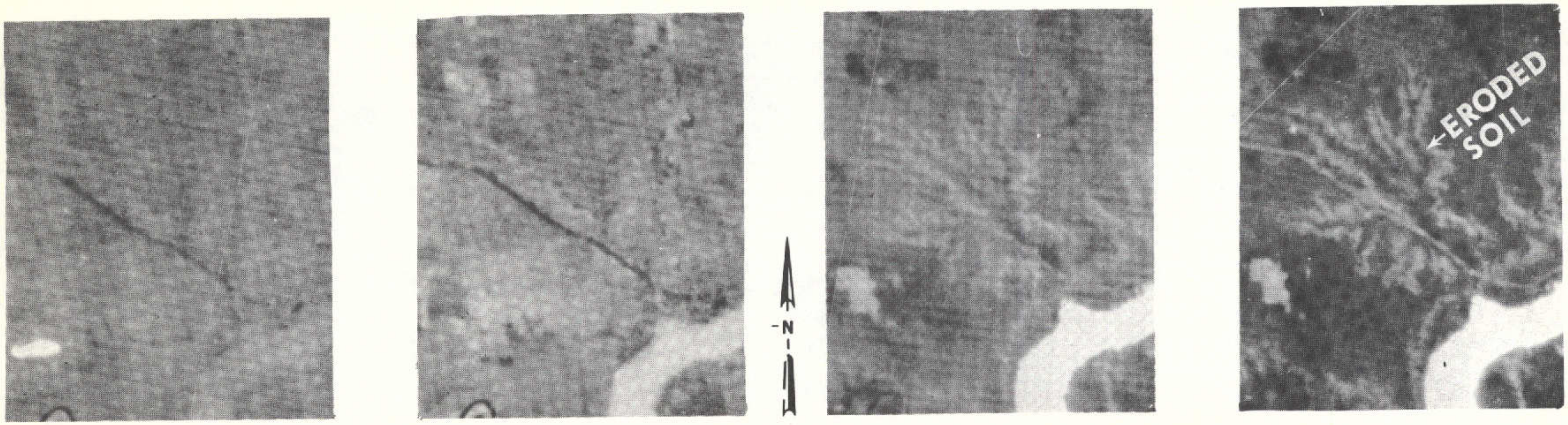
4.4.5 Use of ERTS to Distinguish Soil Erosion. Erosion of critical soil areas such as is taking place above the Missouri River reservoirs and in the badlands is visible on ERTS imagery as is seen in figure 4-12. This figure and the following two illustrate the multispectral advantages of ERTS.

4.4.6 Use of ERTS Images to Identify Vegetation. The radiances recorded by the different bands of ERTS can be used to identify vegetation differences as is shown in figure 4-13.

4.4.7 Use of ERTS Images to Distinguish Open Water from Marshes. Separating water from marsh is a useful technique in soil mapping. Figure 4-14 shows the appearance of open water and marshes on the 4 bands of ERTS.

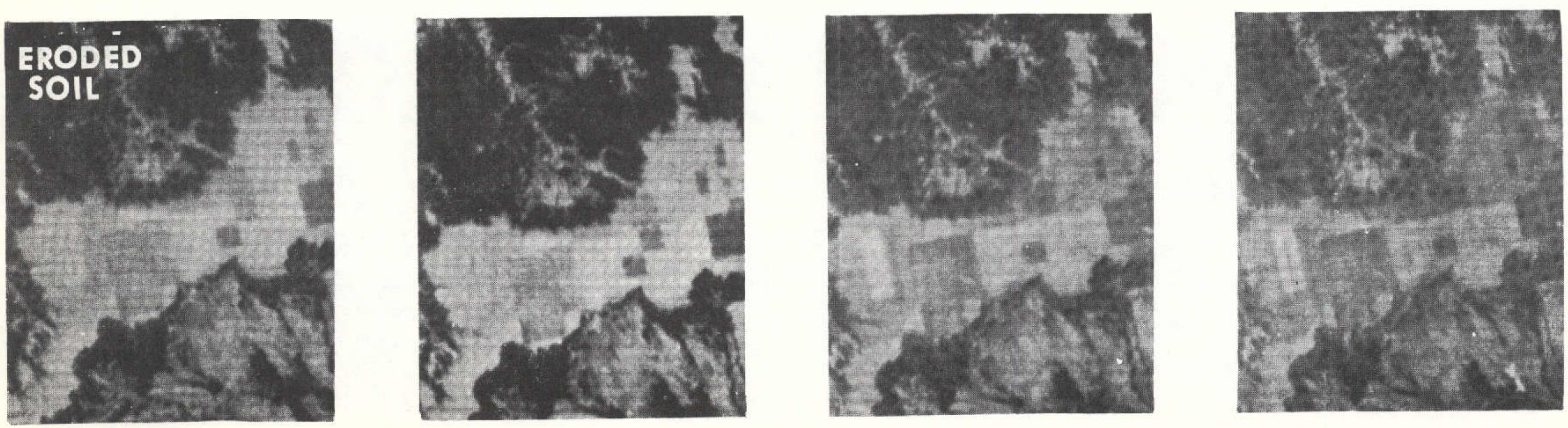
4.4.8 Use of ERTS Computer Compatible Tapes to Distinguish Vegetation Types. Vegetation identification studies of soil associations on two test sites in the Great Plains Area of South Dakota were conducted. Utilized in the study were photographic prints of MSS-5 and 7 at a scale of 1:250,000 and computer compatible tapes. In using the tapes, bands were separated and individual prints of each band were prepared. The data then were removed from the tape and displayed on a printout. Nine hundred scan lines were printed in an 810 X 900 byte area with every other line and every other point printed. A township then was approximately 7.5" X 9" in size. The two study areas were: the shale uplands and Milesville flat area of Haakon County, and the Martin tableland area of Bennett County. In both areas, precipitation is about 16-17 inches annually. The limited precipitation and the unfavorable soil parent material and generally rolling terrain result in grass being the dominant vegetation. Some wheat, milo and alfalfa are raised on more level areas of friable soils and on bottomlands. Farmed fields are large, with quarter section

Erosion of black, shale-derived soils above Missouri River Resérvoir ERTS 1 17 Aug 72 16551



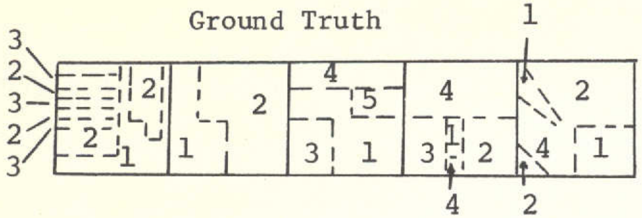
MSS-4 MSS-5 MSS-6 MSS-7

Erosion of light-colored soils in Badlands ERTS 1 19 Aug 72 17065

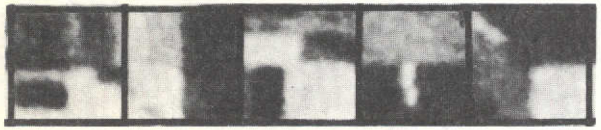


MSS-4 MSS-5 MSS-6 MSS-7

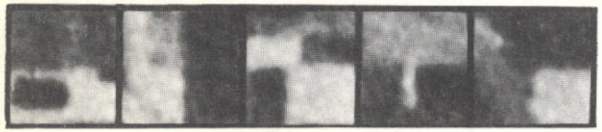
Figure 4-12. Appearance of erosion of black and light-colored soils and sediments on ERTS-1 imagery, negative prints, Scale 1:250,000. Black eroded soils have low reflectance on IR bands 6 and 7 compared to adjacent vegetated areas and stand out as a white fringe. Light colored eroded soils have higher reflectances and thus appear darker on all bands than adjacent vegetated areas.



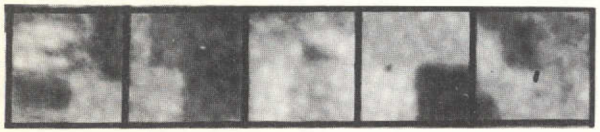
1. Fallow
2. Wheat
3. Milo
4. Native grass
5. Tame grass



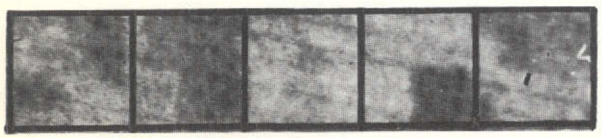
MSS-7



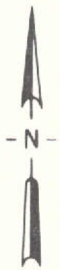
MSS-6



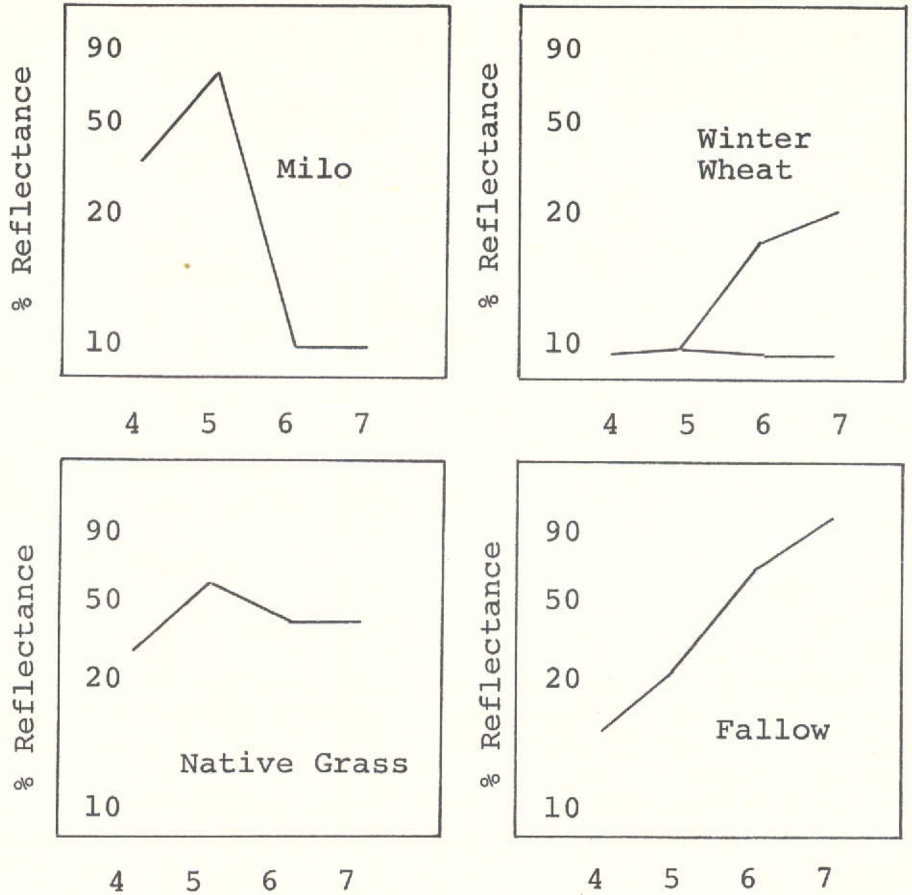
MSS-5



MSS-4



Reflectances on MSS bands 4,5,6 and 7 for crops measured on Macbeth Reflection Densitometer Model RD 219



Wheat and milo can be separated on bands 4 and 5, but not on bands 6 or 7. Fallow and native grass can be separated on bands 6 and 7, but not clearly on bands 4 or 5. Thus, utilizing band 6 or 7, fallow and native grass can be distinguished from each other and from wheat and milo. Then, using band 4 or 5, milo can be distinguished from wheat. Note that on these negative prints the low reflectances have a light tone and high reflectances a dark tone.

Figure 4-13. Identification of crops grown on Soil Association Opal-Promise (Vertic Haplustolls, very fine, montmorillonitic, mesic) on 4 bands of ERTS-1. Negative prints made from black diazo transparencies. Sections 1 through 5 of T106N, R77W, Lyman County, South Dakota, 17 Aug. 72, 16551, Scale 1:100,000.

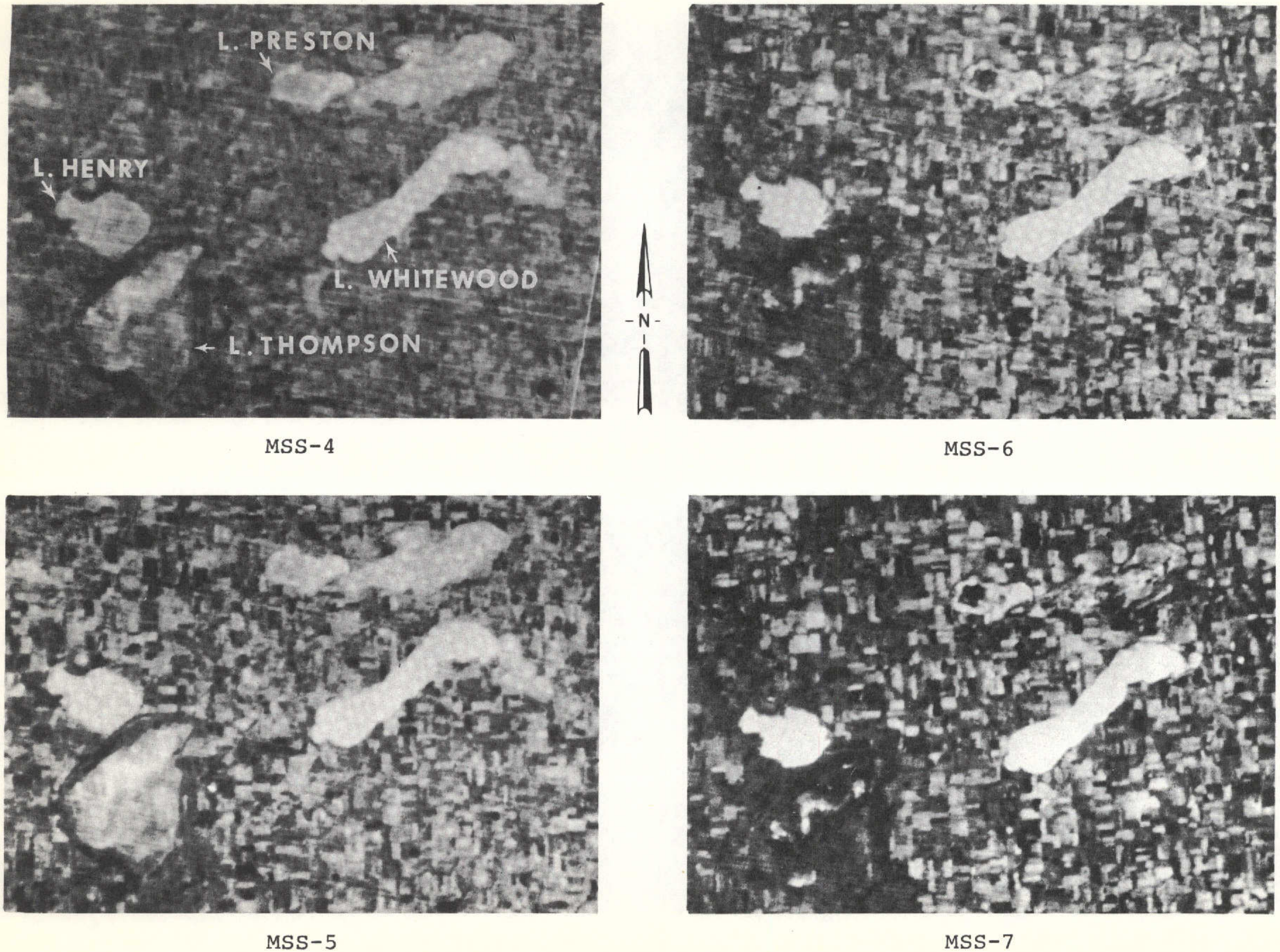


Figure 4-14. Appearance of lakes and marshes on 4 MSS band of ERTS-1 Eastern South Dakota glacial soil areas, 21 Sept. 72, negative prints, Scale 1:250,000.

to half section fields not uncommon. Ground truth for three townships on the Martin Table and two townships in Haakon County was obtained. The CCT printouts were not rectified, so a major problem was to determine the size and shape of sections. After this was determined, an overlay of the ground truth was prepared and readings for the test sections were made. Also made were crop calendar charts to indicate the best image data for each of the dominant vegetation types.

4.4.9 County Planning Maps. Overlays for contour lines, drainage, roads, soils, and incorporated places were prepared on mylar from the color separation plates and superimposed on an ERTS color print of scale 1:250,000 of Gregory County, S. D. made from color composites of MSS 4, 5, and 7. The purpose of this map with overlays was for county planning purposes where data on the basic environmental factors was required. It was found that the mylar overlays fit the ERTS image with no apparent distortion.

4.4.10 Range Site Identification. Ratios of MSS-5 over 7 were composed of a study area one township wide and four townships long in Bennett County to determine if range sites could be discriminated. The two bands were digitized on the Signal Analysis and Dissemination System at a resolution of 36 points per mm. In the range area of South Dakota, the significant soil separations are those that reflect the ability of the soil to supply water to grass. Thus subirrigated range sites are most prized and in these areas grass is growing the most vigorously. Thus these sites would have high radiance readings on MSS 7 and have very low 5/7 ratios. At the other extreme would be the droughty range sites like sands and these sites would have the highest ratios. This study is being continued using ERTS data.

4.4.11 Use of ERTS Imagery in an Operational Soil Survey Program.

The U.S.D.A. Soil Conservation Service is the chief soil mapping agency in South Dakota with about 25 soil surveyors on the staff. In the spring of 1973, the Remote Sensing Institute prepared some black and white imagery of MSS-5 and 7 for study in the field by 7 soil surveyors. These were forwarded to the field by Mr. Donald Bannister, State Soil Scientist and in charge of the S.C.S. mapping program. His comments which are in the form of a letter to Mr. Joe Vitale of the Office of University Affairs, NASA, on the use made of the ERTS imagery are included in this report as appendix A.

4.5 SIGNIFICANT RESULTS:

4.5.1 Soil Association Value Map. Soil association maps for large areas at scales of 1:1,000,000 and 1:500,000 usually are published as line maps or in color. The cost of publishing these maps on conventional aerial photographs would be excessive.[1] A mosaic constructed from ERTS imagery costs relatively little, however, since only 20 ERTS scenes are needed to cover the entire state of South Dakota. Moreover, the image approximates an orthographic view resulting in little distortion. Another advantage of ERTS imagery is that a near real-time view of the scene is afforded, so the current use of the soil associations can be observed and studied. The map also can be updated each year with current ERTS imagery. A Soil Association Value Map of South Dakota on an ERTS-1 mosaic has been published as SDSU-RSI-73-17 and is available from the Remote Sensing Institute, South Dakota State University, Brookings, S.D. 57006. This map, appendix B, was constructed as follows: After delineating the major soil associations with the aid of ERTS imagery, over 4800 land sale prices covering a period of 1967-72 were located in the soil areas and averaged. A legend explaining land use, dominant slope and soil parent

[1] It is estimated that it would take about 30,000 conventional aerial photographs costing $250,000 to cover South Dakota.

materials of each delineated area was developed. The soil associations then were described as Soil Association Value Areas on a 1:1,000,000 scale ERTS mosaic of South Dakota constructed using negative prints of band 7.[2] Negative prints were used because they are a generation closer to the ERTS imagery than positive prints. MSS-7 was used because of its usefulness in detecting growing vegetation, its good contrast, its ability to delineate water and its ability to penetrate haze. The resulting map describes the kind of agriculture and soils and allows readers to see how soils actually are being used on a current map having very little distortion. Furthermore, it gives information about what buyers think the soils are worth. The map is intended for use by state and county revenue officers to equalize land values in South Dakota, by individual buyers and sellers of land and lending institutions as a reference source, as a reference map by those planning road routes and cable lines and pipelines, by conservationists in helping to keep current conservation needs inventories, by agronomists needing current information on distribution and patterns of crop growth and by crop yield forecasters to guide sampling strategy. A letter from the Secretary of Revenue for South Dakota is attached as appendix C to this report which describes the use made by his department of the Soil Association Value Area Map.

4.5.2 Soil Test Results for South Dakota on an ERTS-1 Mosaic. Soil test results since 1954 are summarized on this published mosaic of South Dakota. This map, appendix D, shows any land owner in South Dakota what the status of soil nutrients organic matter and pH is on his soils based on tests that have been made on soils similar to his. These data can aid farmers

2 Appreciation is expressed to Jack Smith, Photographic Technician, RSI, SDSU, Brookings, for preparing the ERTS mosaic of South Dakota

and ranchers to plan their soil fertility programs and also their herbicide programs since herbicide application rates depend in part on soil texture, organic matter and pH.

4.5.3 Soil Test Results for a County on an ERTS-1 Image. Soil test results since 1954 are summarized on this page-size ERTS map of Brookings, County. Ten soil associations are recognized on this map, appendix E, of scale 1:250,000 and soil test data for organic matter, phosphorus, potassium and pH are given for each soil association as well as soil texture and land form. This map was prepared to test reaction of farmers and agricultural technicians to a map of this nature.

4.5.4 Use of the Soil Association Value Area Map on an ERTS Mosaic in Preliminary Site Selection for the Ground Station for the Satellite Space Power Station. The requirements for the rectenna ground station for the proposed Satellite Space Power Station are for a dense soil on relatively inexpensive land used primarily for grazing in an area removed from migratory bird flyways. The Raytheon Engineer (Mr. Owen Maynard), charged with the ground site selection, used the Soil Association Value Area Map published as AES Info Series NO5 on an ERTS Mosaic to tentatively select area "A-1" in western South Dakota as a most promising area. In a personal communication, he stated that he could determine from this map the area best suited for his purpose. The ERTS mosaic showed very little cultivated land in the A-1 area and in the surrounding vicinity. It also showed no chain of lakes or river system which would indicate a migratory bird flyway. The legend gave the information the dominant use of the area was rangeland, that it was a dense soil from shale and that its price was very low ($15-20 an acre).

4.5.5 Use of ERTS as an Educational Tool. The published maps on ERTS imagery previously referenced have been used two semesters in the teaching laboratory in the introductory soils course at South Dakota State University. Their use was in connection with soil survey which normally is considered a dull subject by students. Use of the ERTS maps however has transformed the soil survey exercise into one of considerable interest since students can relate their home area to the whole state. Line maps formerly were used for this purpose and they gave no feel for land use patterns. Students can orient themselves on the ERTS mosaic by lakes, streams and field patterns and study of the soils in their home areas and of the entire state is made interesting and meaningful by the background supplied by the ERTS images. For many students, the interest ignited by the ERTS image has stimulated inquiry into the other facets of ERTS. One such student is now doing graduate work on a soil normalization problem involving ERTS imagery. In addition to the interest of undergraduate students, the ERTS images have been an excellent educational tool for county land assessors in South Dakota. This is attested to in a letter, appendix C. written by Mr. Lyle Wendell, S. D. Secretary of Revenue to Mr. Joe Vitale of the NASA Office of University Affairs.

4.6 SUMMARY AND CONCLUSIONS: ERTS data are a valuable tool to identify soil associations as well as an inexpensive and effective base map upon which to publish soil information. The synoptic view afforded by ERTS scenes allows for the study of the effect of climate and native vegetation on soil patterns. The effect of soil parent material and topography on soil boundaries is provided for best by the comparison of the four MSS channels. These channels coupled with the temporal advantage of ERTS scenes obtained through the growing season provide the best tool for discriminating vegetation

C-2

types so that the use of the soil associations can be determined. Comparison of MSS-5 and 7 of ERTS scenes has been used to detect soil erosion of critical areas above reservoirs along the Missouri River system and in the badlands. In addition, the reflectance differences of the bands provides for a means of discriminating open water and marshland which is a problem encountered in most soil survey operations. The computer compatible tapes of ERTS scenes provide yet another means of studying the soil-vegetative interaction. Determining the individual reflections of MSS-5 and 7 for various crops and other vegetation as well as water, and relating this to ground truth, provides land use signatures. Ratios of bands provide still another dimension to discriminate land use. The histograms accompanying the printouts provide a means for the data to be quantified.

4.7 RECOMMENDATIONS: The ERTS program should continue to be funded. ERTS is a powerful tool to use in the study of soils and the soil-plant relationships, and its potential is just beginning to be realized. Not only is ERTS a tool for identifying and mapping the earth's features but it can also be the vehicle upon which the data can be published. In my opinion there has been no development in soil survey since the use of aerial photos in the 1930's of the significance of ERTS. Aerial photo base maps, although still essential for detailed soil maps are limited in their use for broad soils mapping because they usually are taken in midsummer (a poor time to see soils), they usually are several years old when used, they are somewhat distorted, and they provide an image which covers only a small part of the terrain, and only in the visible part of the spectrum. Thus they are often used only as a map upon which to record soil lines. The temporal, multisensor, near-orthographic imagery of ERTS is an exciting development which needs only more time and research to become an even more powerful tool for soil survey.

4.8 PUBLISHED PAPERS AND MAPS:

1. Westin, Frederick C. and V.I. Myers. 1973. Identification of Soil Associations in Western South Dakota on ERTS-1 Imagery. Symposium on Significant Results Obtained from Earth Resources Technology Satellite-1. Vol. 1. Technical Presentations, Section B, page 965-972. Goddard Space Flight Center, New Carroleton, Md. March 5-9, 1973.

2. Westin, Frederick C. 1973. ERTS-1 MSS Imagery: A Tool for Identifying Soil Associations. To be published in Proceedings of Symposium on Approaches to Earth Survey Problems Through the Use of Space Techniques. Presented at General Assembly of Committee on Space Research (COSPAR), Konstanz, West Germany, May 25, 1973. Preprint available. To be published in COSPAR Proceedings.

3. Westin, Frederick C. 1973. Identification of Soil Associations in South Dakota on ERTS-1 Imagery. Symposium on Management and Utilization of Remote Sensing Data. The American Society of Photogrammetry. Symposium Proceedings, pages 610-629, Sioux Falls, S.D. Oct 29 - Nov. 1, 1973.

4. Westin, Frederick C. 1973. ERTS-1 MSS Imagery: Its Use in Delineating Soil Associations and as a Base Map for Publishing Soils Information. To be published by N.A.S.A. - Goddard S.F.C. Mimeo available. Presented at Third ERTS Symposium Dec. 10-14, 1973. Statler Hilton Hotel, Washington, D.C.

5. Using ERTS-1 Satellite Photos for Agriculture, in Soils and Sales, S. Dak. Farm and Home Research. Ag. Expt. Sta. S. Dak. State University Vol. XXIV Summer 1973. No. 2.

6. Lemme, Gary. Vegetation and Water Identification of One Township of Land in Bennett Co. S.D. Using Digital Tape From ERTS-1. Abstract to be published in the S.D. Academy of Science Proceedings in 1974.

7. Moore, D.G. and F.C. Westin. ERTS Data as a Teaching Tool in Regional Physical Geography With Special Reference to South Dakota. RSI No. SDSU 74-05. To be published in the S.D. Academy of Science Proceedings in 1974.

8. Westin, F.C. ERTS Mosaic of South Dakota Showing Soil Association Value Areas AES Info. Series No. 5. Ag. Expt. Sta. and Remote Sensing Institute SDSU RSI-73-17. (A mosaic of scale 1:1,000,000 Showing Soil Delineations for Which Information is Given on Soil Dollar Values, Soil Textures, Land Forms and Parent Materials).

9. Westin, F.C. Soil Textures and Land Forms on ERTS-1 Imagery, Brookings County, South Dakota. AES Info Series 8. June 1974. A county map showing soil test results and textures for 10 delineations with instructions for use to determine soil nutrient status and as an herbicide guide.

10. Westin, F.C. Soil Test Results for Soil Associations on an ERTS Mosaic of South Dakota. AES Info Series 7 Ag. Expt. Sta. and Remote Sensing Institute SDSU RSI 743 SDSU Brookings.

5. SOIL INFLUENCES IN CROP IDENTIFICATION:

5.1 GENERAL OBJECTIVE: Crop radiances from computer compatable tapes of the cropland study area (Report Section 3.0) contained background influences caused by soil differences. The objective in this section was to account for individual soil differences so that more precision can be gained in crop identification.

5.2 SPECIFIC OBJECTIVES:

5.2.1 To determine the radiance values for each soil involved.

5.2.2 To determine if these values permit refinement of crop identification.

5.3 VARIABLES UNDER INVESTIGATION:

5.3.1 Soils. The study area was divided into three major soil associations:

(a) An upland area of silty soils derived from loess and lying on gently undulating topography;

(b) A bottomland of medium textured, moderately well drained soil;

(c) A bottomland area of fine-textured, moderately well drained soils.

5.3.2 Crops. The major crops included corn, soybeans, alfalfa, oats and grassland.

5.3.3 Imagery

(a) ERTS for May, June and August, 1973, MSS-5 and 7.

(b) RB-57 color and black and white photos.

5.3.4 Ground truth included a complete inventory of the land use in the study area. Some ground photos also were used.

5.4 PROCEDURES:

5.4.1 Prepare a mylar overlay of soils in the study area utilized for section 3.0 of this report.

5.4.2 Prepare a mylar overlay of field boundaries in the same area. This process was greatly aided by the preparation of a printout of boundaries utilizing a boundary detection program developed at the Remote Sensing Institute (Russell, Moore and Nelson, 1974)[1].

5.4.3 Printout the digitization of bands 5 and 7 for the study area.

5.4.4 Superimpose the field boundary overlay on the digitized printout and identify crops, soils and fields by number.

5.4.5 Record the range of digitized values and the dominant values for each field. Plot and interpret the distribution of values stratified for soils and crops.

5.5 ACCOMPLISHMENTS:

5.5.1 Location of field boundaries and preparation of overlays.

5.5.2 Determination of range of radiance values and dominant values for three separate soil associations.

5.5.3 Plotting of the radiance values so that the effect of soil differences could be determined.

5.5.4 Determination of ratios of MSS 5/MSS-7 to separate out radiance values caused by crops and soils. This has so far been accomplished for the May 30 imagery with partial results for July and August imagery.

5.6 SIGNIFICANT RESULTS:

5.6.1 The boundary detection algorithm is useful in locating field boundaries or other natural boundaries on a digitized printout.

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[1] Russell, M., D.G. Moore, and G.D. Nelson. 1974. Boundary Detection Procedure Developed for Application to Evapotranspiration Assessments. Advanced Report of Significant Results submitted to NASA Contr. 9-13337, in press. RSI-74-10.

5.6.2 The effect of the 3 soil conditions studied can be measured and accounted for. To do this requires imagery during periods of full canopy as well as when the soil is bare.

5.6.3 The use of band ratioing techniques presents a promising approach to separating out the effect of soil on crop radiance data. Ratios alone however, are not sufficient but the radiance level must also be included in order to achieve precise results.

5.6.4 The significant results are summarized in the following charts and tables. On each chart, both the upper and lower limits of radiance values are shown for each band. Dominant reflectances within each range are shown by the letter code between the range lines. Field numbers and soil types are listed across the top of the chart, i.e. AIU = Alfalfa, field 1, upland; A10B = Alfalfa, field 10, bottom land; C6U = corn, field 6, upland etc.

(a) A chart showing range and dominant reflectance of alfalfa on MSS-5 and 7 for May 30, 1973 was completed (fig. 5-1).

(b) A chart showing range and dominant reflectances of corn on MSS-5 and 7 for May 30, 1973 was completed (figs. 5-2, 5-3 and 5-4).

(c) A table showing effect of soils on 5/7 ratios for 5 vegetative types was completed (Table 5-1). The 5/7 ratios were considerably different for corn and soybeans growing on different soils; however, the ratios for full canopy crops, alfalfa, and oats, were more constant.

5.7 SUMMARY AND CONCLUSIONS:

5.7.1 Accurate location of field boundaries, precise ground truth and exact imagery registration are essential for

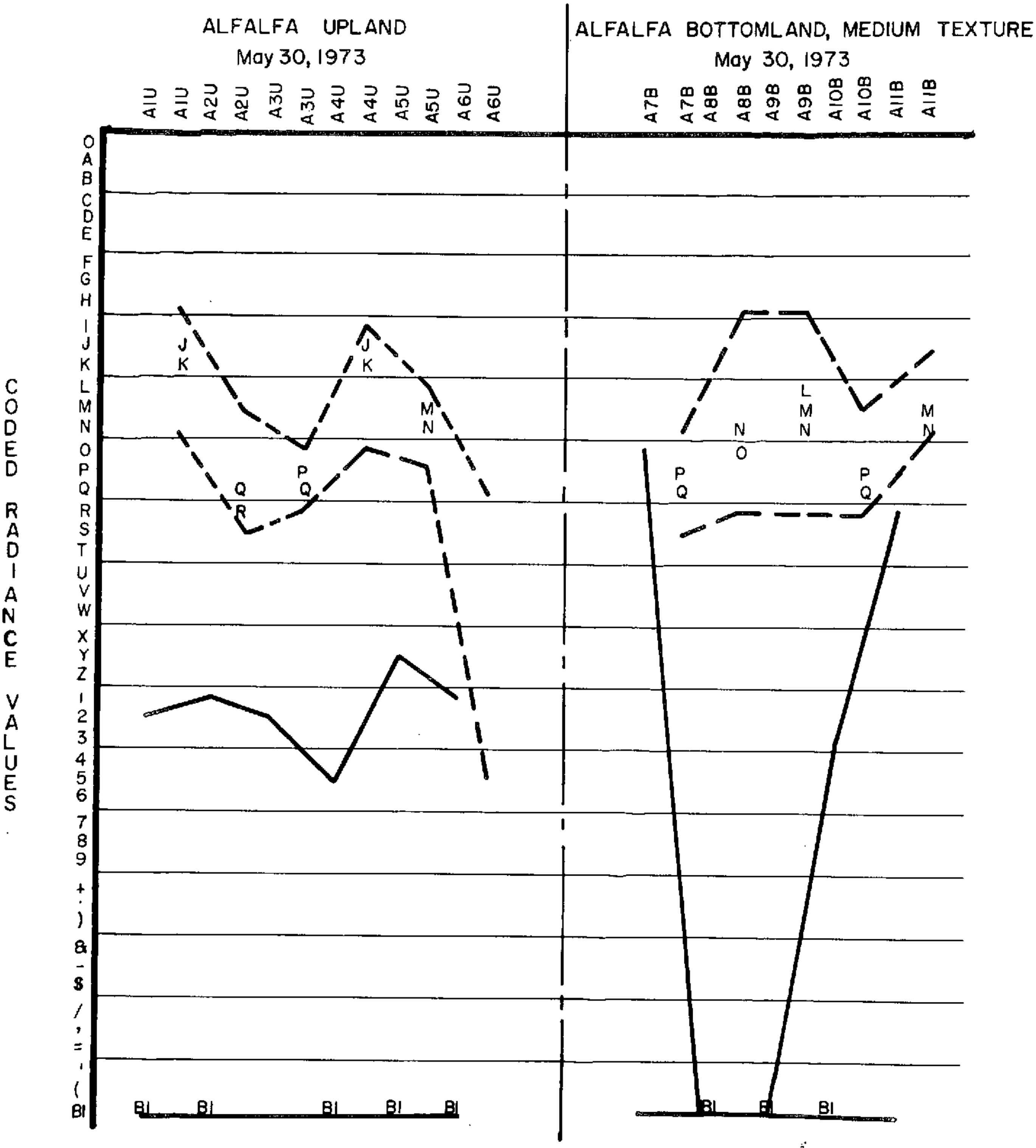


Figure 5-1. Distribution of radiance values across fields (--- Band 5, —— Band 7).

CORN UPLAND
May 30, 1973

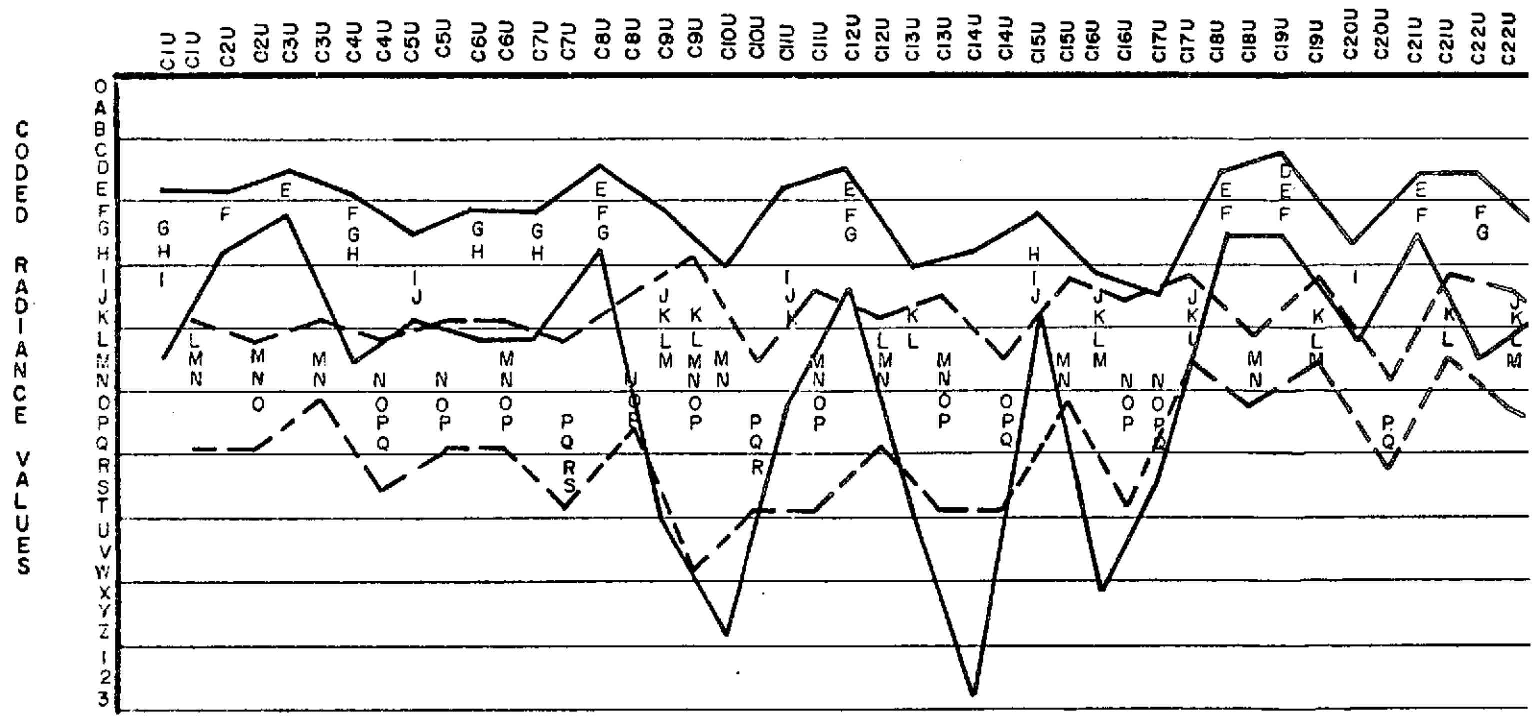


Figure 5-2. Distribution of radiance values across fields (--- Band 5, —— Band 7).

CORN UPLAND
May 30, 1973

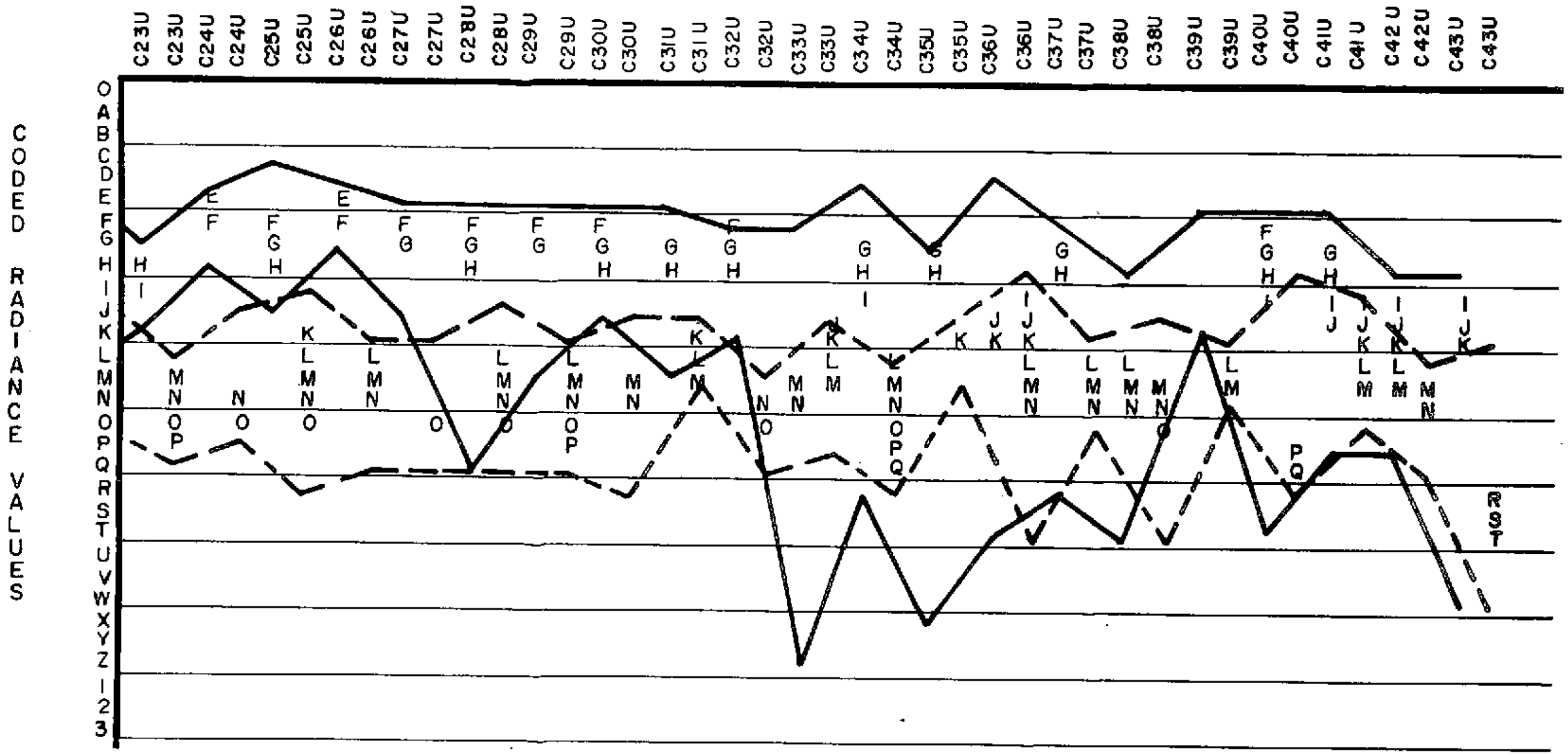
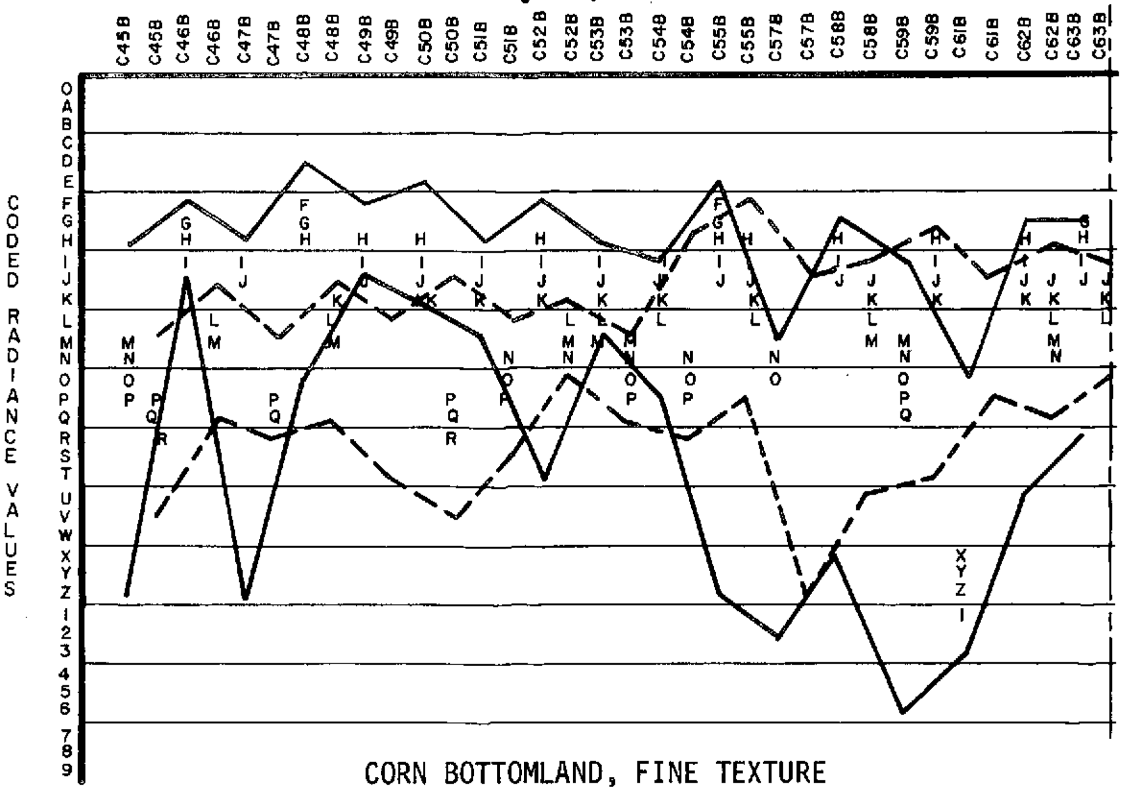


Figure 5-3. Distribution of radiance values across fields (--- Band 5, —— Band 7).

CORN BOTTOMLAND, MEDIUM TEXTURE
May 30, 1973



CORN BOTTOMLAND, FINE TEXTURE
May 30, 1973

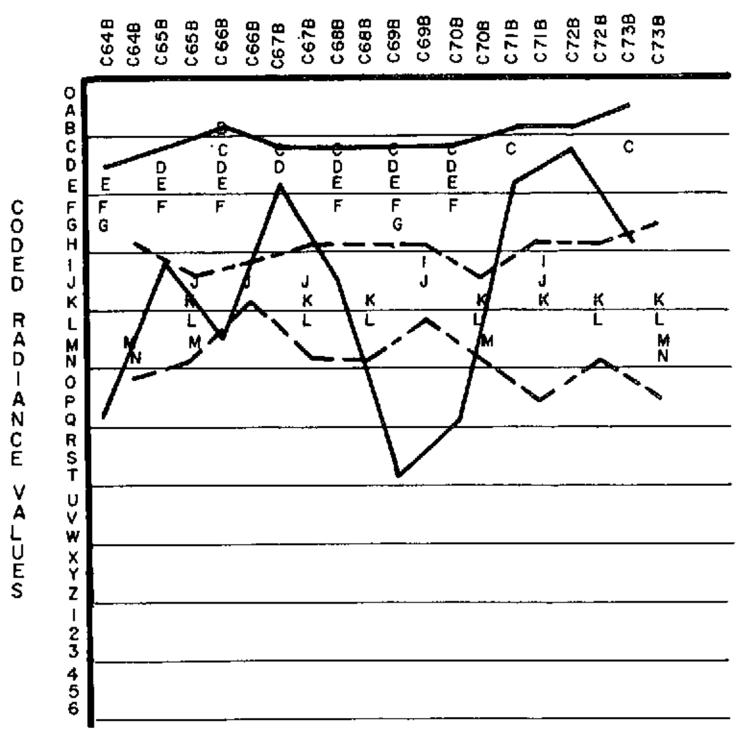


Figure 5-4. Distribution of radiance values across fields (--- Band 5, —— 7).

Table 5-1. Effect of Soils on MSS 5/7 ratios for 5 vegetative types. ERTS Image of May 30, 1973 Centerville Test Site, Clay County, S.D. One hundred thirty eight fields plus Meadow Land of Vermillion River were included in the test. The number of fields tested for each soil-crop combination is shown in parenthesis after the ratios.

	Corn	Soybeans	Oats	Alfalfa	Grass
Upland Silty Soils	1.75(43)	1.87(33)	1.07(17)	0.35 (6)	
Medium-textured Bottomland Soils	1.33(20)	1.27(6)	1.37(4)	0.33 (10)	.43
Fine-textured Bottomland Soils	2.40(10)	2.75(5)	-(0)	-	

successful use of ERTS imagery for identification of vegetation.

5.7.2 Differences in radiance values for different crops can, in part, be accounted for by soil differences. Other factors are difference in stage of growth and ripening of crops, fertility, water supply, and temperature differences, or to purity of crops which could include weeds or mixture of crops.

5.7.3 The initial encouraging results need to be followed up by additional studies on the influence of soils and crop variation using ERTS imagery.

5.8 RECOMMENDATIONS:

5.8.1 Controlled experiments involving different crops, different crop varieties and major soil associations should be conducted utilizing ERTS imagery, and involving several stages of growth over a period of time extending from May through September.

5.8.2 Models for vegetation prediction appear to be feasible if step 5.8.1 were followed. The step following vegetation prediction models will be vegetation yield models. In order for this to be operational however, it would be necessary to cut down the time lag for receiving ERTS imagery.

6. DATA HANDLING:

6.1 SPECIFIC OBJECTIVES:

6.1.1 Evaluate and/or propose boundary detection algorithm to detect landforms, land use, and vegetative types.

6.1.2 Evaluate and/or propose features to be measured which can be used to identify landforms, land use and vegetative types from ERTS precision multispectral scanner data.

6.2 PROCEDURES:

6.2.1 Use boundary detection algorithms on precision multispectral scanner data to determine their effectiveness.

6.2.2 Propose a set of features and use them to determine landforms, land use and vegetative types from ERTS multispectral scanner data.

6.2.3 Demonstrate the effectiveness of the interactive data processing system to investigators so that it can be used by them in pattern recognition, agriculture and hydrology.

6.3 DATA PRODUCTS:

The original standing order for ERTS data products called for two copies of the bulk 9.5 inch positive transparencies for all RBV and MSS bands with a cloud cover tolerance of 50%. The area of coverage included the entire state of South Dakota. It was later decided by the investigators that the standing order cloud cover tolerance should be changed to 100%. An extensive data request was sent in to backorder the imagery with 50-100% cloud cover. The standing order was again changed early in 1974 to include one copy of the bulk 70 mm positive transparencies for all MSS bands. This change was prompted by the fact that an I^2S color additive viewer which uses the 70 mm chips for its operation was purchased. Catalogs and microfilm for all U.S. and non-U.S. imagery was also received throughout the entire contract period. Computer compatible tapes for selected areas in

South Dakota were ordered as needed by the investigators.

6.4 DATA HANDLING EQUIPMENT: Equipment used for the analysis of ERTS data products included an I^2S color additive viewer, the South Dakota State University IBM 370/145 computer system, and the Signal Analysis and Dissemination Equipment (SADE) system. A detailed description of the SADE system is found in Appendix F.

6.5 DATA HANDLING ACCOMPLISHMENTS:

6.5.1 The accomplishments of the data handling section of this investigation consisted basically of the techniques that were developed for the handling of both the photographic and digital ERTS data products. Although many techniques were merely refinements of standard procedures, many other techniques required extensive development time and effort. Specific techniques which were used for the various phases of the investigation are described in applicable sections of this report.

6.5.2 Because of the large amount of ERTS photographic imagery which was received for our standing order, it was necessary to maintain an imagery library. Procedures for filing, labeling, and cross-referencing were developed. Separate files were kept for imagery which was available for general use and imagery which was used for machine analysis.

6.5.3 Data in digital format was obtained from CCT's and SADE digitization. Processing of this data included line printer output (in numeric or symbol format), video monitor displays, ratioing the values from the various bands, conversion to radiance values, merging data from the four bands, etc.

6.5.4 Statistical techniques included correlation of ERTS and ground truth data, deriving multiple regression equations, analysis of variance and other standard statistical procedures.

The supervised K-class and unsupervised mode-seeking classifier algorithms were used extensively. A boundary detection program was also developed and used on ERTS data. Detailed explanations of the K-class, mode-seeking programs follow in sections 6.5.5 and 6.5.6.

6.5.5 K-class. The K-class classifier calculates a decision vector D with K-elements where

$$D = B\ X_A.$$

X_A is an augmented feature vector of length (n + 1); that is

$$X_A = (X \vdots -1)^T.$$

The first n-elements are the features or measurements which represent the data. The B matrix is derived by minimizing the least-squares mapping error of the augmented feature vector X_A toward the orthoclass vectors δ^e. The orthonormal class vectors are actually only the unit vectors in three-dimensional space. In K-dimensional space where K is four, the orthonormal class vectors are:

(1000), (0100), (0010), (0001).

Mathematically this minimization is

$$\nabla_B\ \overline{(\delta^e - BX_A{}^e)^T\ (\delta^e - BX_A{}^e)} = 0$$

and the solution for the optimal transformation matrix is

$$B = P(\overline{X}_j{}^i)^T\ \overline{(X_A X_A{}^T)}^{-1}.$$

The decision vector is

$$D = P(\overline{X}^i - \overline{X})^T\ \phi^{-1}\ (X - \overline{X}) + P$$

where the i^{th} element d_i is

$$d_i = p_i\ (\overline{X}^i - \overline{X})^T\ \phi^{-1}\ (X - \overline{X}) + p_i$$

The sample covariance matrix is

$$\phi = \overline{XX^T} - \bar{X}\bar{X}^T$$

and ϕ^{-1} is its inverse.

The i^{th} element depends on the inverse of the sample covariance matrix which in turn depends on the variance of each measurement and the correlation between measurements. Also, the i^{th} element depends on the mean value of the i^{th} class occurring. To train the K-class classifier the investigator needs to have a training set of data. This set consists of sample data from each class of interest. The mean of the feature vector for each class and the mean of all classes is calculated. The covariance matrix and its inverse are also calculated. The only unknown in the equations for the decision vector elements is the feature vector to be classified. The decision is calculated by selecting the maximum element value d_j. The feature vector X is assigned to class j. By this procedure a classification map of an area can be made whether the feature vector represents one or n measurements.

6.5.6 MODE-SEEKING:

(a) The basic assumption in cluster analysis is that the data has local concentrations, or clusters. In general, the cluster analysis problem is to discover these clusters and classify the data into classes corresponding to the natural clusters. The mode seeking algorithm tries to locate the centers of the clusters or modes. In order to terminate the mode seeking process at an appropriate time, it is necessary to specify the maximum number of modes permitted for a given set of data. This requires a priori knowledge regarding the possible number of classes present in the given data set. To start with, the first sample in the data set is made the center of the first cluster. Thereafter, the samples in the data set are considered one at a time. For each sample, the algorithm calculates the distance from the sample to the centers of all the existing clusters and thus finds the cluster to which the sample is nearest. If the sample is within a certain specified distance, called the "cluster threshold", the sample is assigned to that cluster. Whenever a sample is assigned a cluster, the center as well as the grade of membership, representing the number of samples contained in that cluster or mode, are updated to take into account the effect of the newly added sample in the decision making process. For example, if a sample with coordinates (x_2, y_2) is added to a cluster containing n samples with its center at (x_1, y_1) the updated center and the grade of membership are given by

$$c(x,y) = c\left(\frac{n_1 x_1 + x_2}{n_1 + 1}, \frac{n_1 y_1 + y_2}{n_1 + 1}\right)$$

and $n = n_1 + 1$, respectively.

If the distance from a sample to the nearest cluster is more than the "cluster threshold", a new cluster is initialized with that particular sample as its center. Whenever a new cluster is formed, the number of clusters thus far found are compared with the maximum of allowable clusters. If it does not exceed this limit the algorithm will proceed to consider the next sample. On the other hand, if the limit is exceeded, the particular iteration is terminated at that point, the "cluster threshold" is increased by a certain specified multiplication factor and the process is repeated starting from the first sample. Thus every iteration in the mode seeking process considers all the samples in the given data set, thereby eliminating what is called the "unclassificable points". The mode seeking process comes to an end at the end of iteration, if the number of modes found during that iteration is less than or equal to the allowable number of modes. Once the modes that are present in a set of data are found, the next step in the pattern recognition problem is to identify every sample in the data set by its cluster membership. This will enable one to produce an output map showing the patterns in the imagery from which the data set is derived.

(b) A computer program was written for the data identification process. In this program the samples in the data set are considered one at a time. For each sample, the distance from it to the center of all the modes, found during the mode seeking process, are calculated and hence the mode that is nearest to the sample is found. Accordingly, the sample is coded with the code for the nearest mode, indicating that the sample belongs to that mode. When all the samples are thus coded, an output map can be produced in terms of sample codes. If necessary, these sample codes can be converted into appropriate photographic grey levels and the classification results can be displayed on a color TV screen.

(c) The results of the mode seeking algorithm can be used as input to the K-class classifier. Classification by the K-class classifier is defined as the assignment of an event to one of K mutually exclusive subsets of events, called classes. An event is characterized by a set of measurable parameters, "features" or "attributes", and by an abstract set of parameters not amenable to direct measurements - the "class parameters". An event is then described by (d,x) where d is the class vector and x is an attribute vector. Classification may now be defined as the determination of the class vector, d, given only the original measurements, x, for a given event. The K-class classifier requires the following information:

1. A training set of data to train the classifier. The researcher must specify the number of data points in each class and store it sequentially by class. This is necessary for the classifier to calculate the class means.

2. A priori probability of occurrence of each class.

The results of the mode seeking process provide the required K-class information as follows:

1. The coded samples which are the output of the mode seeking algorithm may be used for training the classifier.

2. The number of samples in any mode divided by the total number of samples gives a measure of a priori probability of occurrence for that class.

P. O. Box 1357, Huron, South Dakota 57350

July 10, 1974

Mr. Joe A. Vitale, Chief
Engineering Systems Design Branch
Office of University Affairs
NASA Code Y Room 6125
400 Maryland Ave. S. W.
Washington, D. C. 20546

Dear Mr. Vitale:

Dr Fred C. Westin suggested that you may be interested in some of the work initiated in South Dakota exploring methods in which ERTS imagery may improve or accelerate our soil survey program. In March, I forwarded black and white ERTS imagery at 1:1,000,000 and 1:250,000 scales, Band 5 and Band 7, to selected soil scientists. The purpose as outlined to them was to keep ourselves up to date on the type of data that is available, and to seriously review and study the imagery for any methods in which it may assist us in our soil survey program or land use interpretations. Some of the things we suggested for consideration were:

1. Refining or sharpening of our general soil association areas

2. Would it assist us in outlining general areas of different soils that do not seem to appear on our present photography; for example, would it help us separate some of our silty drift areas or geologic areas that may be reflected in our soil survey delineations?

3. Broader vegetative or land use patterns that may be indicative of soil patterns.

4. The possibility of using the ERTS background at a 1:250,000 scale for more impressive demonstration, educational, or informational uses.

The ERTS imagery was furnished us by the Remote Sensing Institute at Brookings. We hope to follow up this project with some 1974 ERTS imagery for study by field soil scientists. The Remote Sensing Institute also has furnished us a few selected color composites which will be evaluated.

I am attaching copies of the original comments received from our field soil scientists. Our soil survey staff has not yet appraised or followed up with our soil scientists on this project. This will be done this winter. In some cases, we plan for personnel of the Remote Sensing Institute to work with our people on interpretation of this imagery. I appreciate the excellent cooperation of the personnel of the Remote Sensing Institute and Plant Science Department at South Dakota State University in working with this data.

I believe it is evident that in some counties the imagery will assist us in more accurately delineating broad soil areas in addition to other features as geologic areas and land use patterns. Before drawing any conclusions for use in soil survey, it is necessary that we follow up with our soil scientists during FY 1975.

Sincerely,

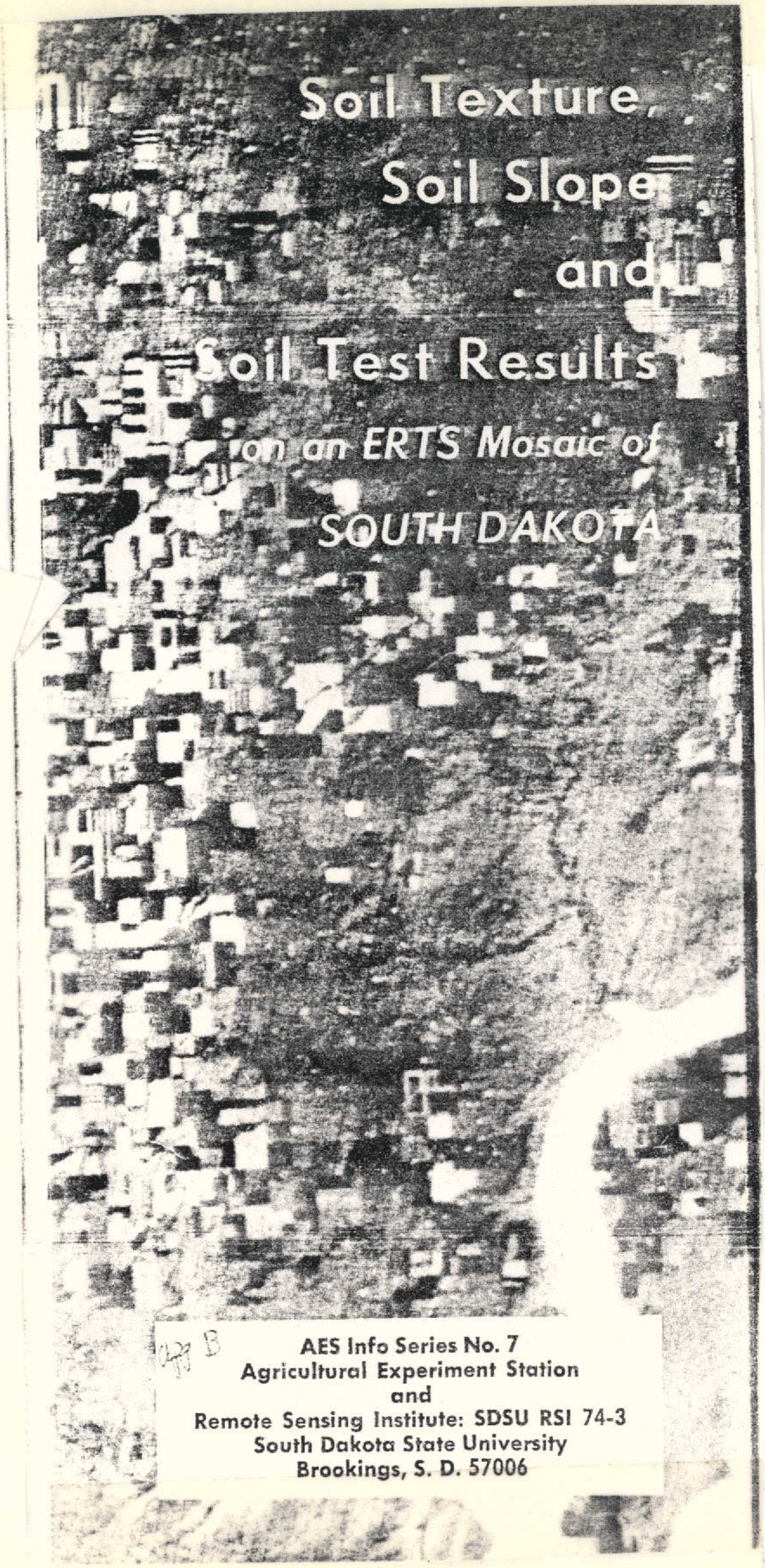
D. G. Bannister
State Soil Scientist

Attachments

cc: Dr. Fred C. Westin, SDSU, Brookings

ORIGINAL PAGE IS
OF POOR QUALITY

MAP NOT FILMED



APPENDIX B.

Dakota
Department of Revenue

DIVISION OF PROPERTY TAXES
State Capitol Annex
Pierre, South Dakota 57501
Phone 605/224-3311

July 5, 1974

Joe A. Vitale, Chief
Engineering System Design Branch
Office of University Affairs
NASA Code Y Room 6125
400 Maryland Avenue S. W.
Washington, D. C. 20546

Dear Mr. Vitale:

I believe it is proper that you share our feelings concerning the publication entitled "ERTS Mosaic of South Dakota Showing Soil Value Areas". It has already proved to be extremely helpful in carrying out a portion of our statute relating to agricultural land values that are based on certain criteria set out by the legislature. It is, in fact being used to carry out the intent of our legislature in the area of land evaluation.

Our problem of state-wide rural land assessment is to achieve equalization within and between counties, to achieve this requires an overall look at the state. One way of getting this overall look is with a photograph or image taken of the entire state at about the same time. This does make comparison possible and comparable properties are extremely important in the area of any equalization program for taxation purposes. This can be achieved with the help of the ERTS image.

In South Dakota our index for determination of land values is the percent of land under cultivation. The ERTS image does indicate the land use. South eastern South Dakota counties like Hutchinson and McCook are almost 100% under cultivation, others in northeastern South Dakota like Grant, Roberts and Marshall include a wide land of hilly, lower price land in grass. The image also shows a wide swath of lower priced land (c7) in north central South Dakota. An inspection of these land patterns show a substantially lower percentage of crop land in these areas. So you can see that ERTS image serves a double purpose for us here, it is a base map for platting value delineations and it helps to explain why the value delineations are different.

In western South Dakota the crop land primarily is on tablelands between major drains. These tablelands are most easily seen on your ERTS image, their shape and size can be accurately platted and by understanding of what the black, gray and white tones mean and the kind of agriculture practiced in the area can be deduced. This we are able to do with the tremendous help given to us by South Dakota State University at Brookings, South Dakota.

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APPENDIX C.

From our point of view one of the most significant contributions of the ERTS land value map is that it will build up confidence between the County Director of Equalization office and our own Property Tax Division because the values placed will fit a state-wide pattern of assessments.

This particular use of the ERTS land value maps will give us a systematic approach to assessment in the state of South Dakota and most certainly can be nothing but beneficial in helping explain land assessments to farmers and ranchers in South Dakota.

Very truly yours,

Lyle Wendell
Secretary of Revenue

LW/GW/b

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Soil Textures and Land Forms on ERTS-1 Imagery

AES Info Series 8
June 1974 (Revised)

Plant Science Department, Agricultural Experiment Station, and Remote Sensing Institute, South Dakota State University, Brookings.

ERTS image of 17 June 73. Negative print of Band 7 Infrared. Water reflects white, bare soil very light gray, actively growing vegetation dark gray.

SCALE: 1:250,000
(1 inch=4 miles)

———————— Roads

Funded in part by the State of South Dakota and NASA University Affairs Office, Grant 42-003-007

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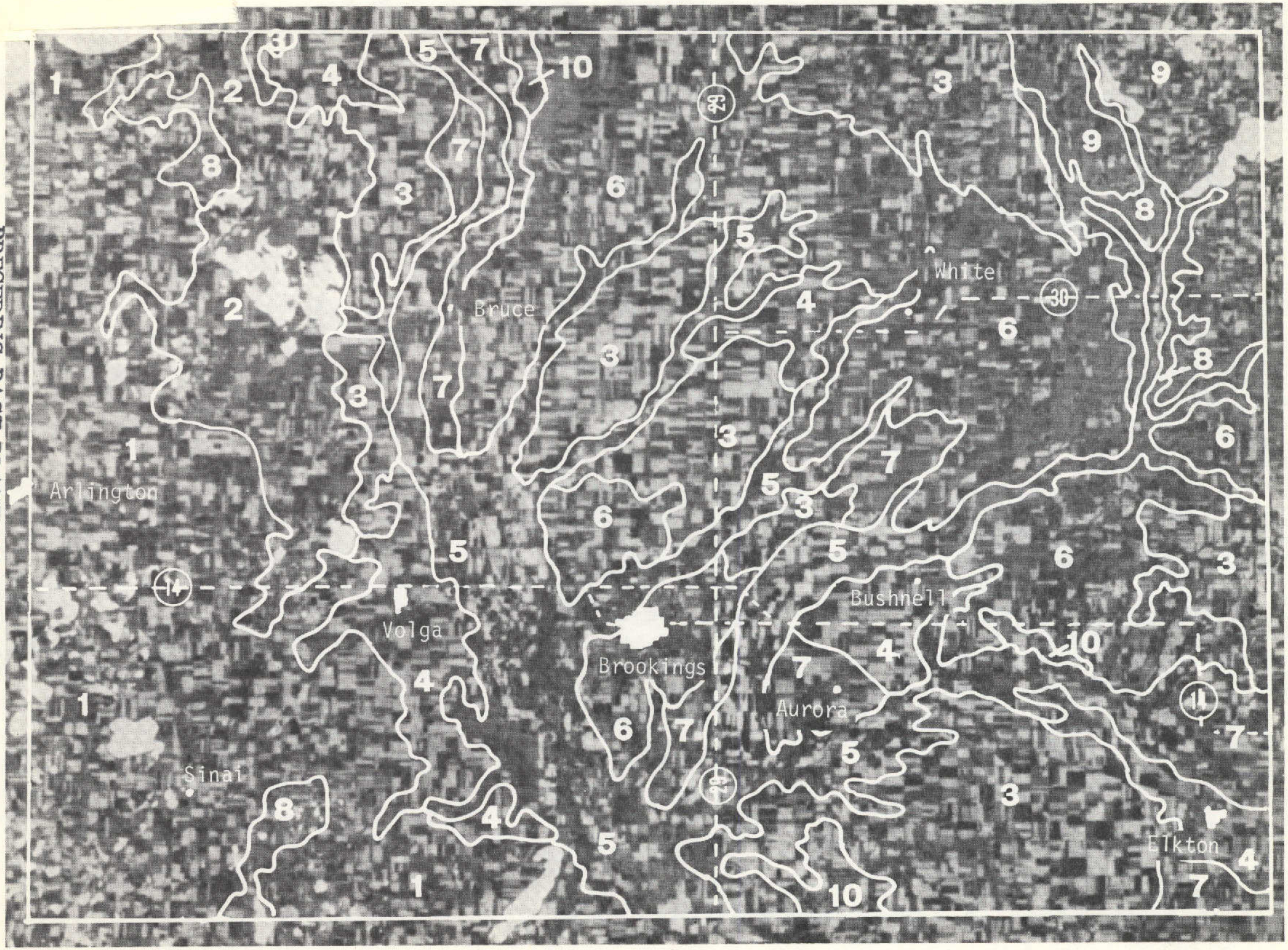
Brookings County, South Dakota

APPENDIX E.



Use of this soil information discussed on reverse side.

1—Silty Clay Loams (undulating upland with marshes and lakes).
2—Silty Clay Loams and Loams (rolling upland with marshes and depressions).
3—Silty Clay Loams (sloping upland with stream drainage).
4—Silty Clay Loams (flat terrace, gravel substratum).
5—Silty Clay Loams and Clays (flat bottomlands, often wet, with variable depth to gravel).
6—Loams (sloping upland with stream drainage, may be stony).
7—Loams (flat terrace, gravel substratum).
8—Loams (hilly or steep uplands).
9—Loams (undulating upland with marshes and depressions).
10—Sandy Loams and Light Loams (sloping upland with stream drainage).

APPENDIX F.

SIGNAL ANALYSIS AND DISSEMINATION EQUIPMENT

Introduction

The Signal Analysis and Dissemination Equipment (SADE) system has been developed at the Remote Sensing Institute as a state-of-the-art system for remote sensing data handling and analysis. This system, which is linked directly to the South Dakota State University computer center, is modular in design, thereby producing a system with great flexibility and outstanding capabilities.

SADE System Features

1. High resolution, high quality digitization of black and white and color film transparencies
2. Accommodation of 35 mm, 70 mm and 9½ inch single frame or roll film
3. Multiple frame registration on-line
4. Off-line registration
5. Digitization of analog magnetic tape information (one to six channels)
6. A solid state memory for the display of processed data on the video monitor and for registration
7. Expandable memory for storage of high resolution imaged data
8. Conversion of processed digital data to hard copy using an output printer (70 mm film) or by photographing video monitor
9. Control of the system's components in communications with the computer via teletype and system control panel

SADE System Configuration - Hardware

1. The Spatial Data unit serves as a monitor for displaying video information in 16 black and white or color levels. Color analysis is controlled by a pushbutton keyboard, and an electronic digital planimeter measures the relative areas of one or more color bands. Also included in the Spatial Data unit are a closed-circuit television camera and a light box which can be used in conjunction with the monitor to form a 32-level analog image analysis system which is independent of SADE.

2. The Dicomed D57 Image Digitizer is configured to accommodate 35 mm, 70 mm and 9½ inch roll film with manual film translation and rotation. It scans a 57 x 57 mm area of positive or negative transparency, color, or black and white film. The digitizer has a density range of 0.05 to 2.45 density units.

The image dissector tube (IDT), focusing lens, deflection system, and electronics are located in an optical assembly above the film plane. A hood shields extraneous light during the digitizing process. The film is held between a set of glass plates mounted on a large, flat, movable surface. A 350-watt tungsten Halogen lamp and condensing lens are mounted beneath the glass film holder in the cabinet along with the electronics and operator panel. A holder is provided for filters.

3. The Data Conversion Unit (DCU) contains the following hardware:
   a. Fabri-tek Memory
   b. Fabri-tek Memory Power Supply
   c. Atron Controller (DFM)
   d. Three Logic Decks

      Deck A
      - High Speed Memory (HSM) Interfaces

      Deck B
      - 2701 Local Interface
      - Printer Interface
      - TTY Interface

Deck C

- Analog Tape Converter (ATC)

e. Five Logic Power Supplies

f. One Control Panel

g. One Connector Panel

The Atron Controller located in the DCU will perform the following functions:

(a) Subdevice communication service

(b) Update of HSM addressing and data

(c) D57 to HSM image store and image interface

(d) ATC to monitor HSM, image move down

(e) 2701 to HSM, image move down and image move up

(f) D57 to 2701 (bypass)

(g) ATC to 2701 (bypass)

(h) Subdevice selection

The Data Format Module is a subdevice of the Atron controller. Four types of large printed circuit cards are used in the DFM -- Read Only Memory (ROM), Read/Write Program Memory (R/WPM), Microprocessor, and Input-Output (I/O). Two (I/O) cards are used to provide the four interface channels (two channels per I/O card) which supply all of the communications between the DFM and DCU. The DFM has no switches or indicators and is completely controlled by the signals it receives via the four interface channels. Channels one through four are interfaced to the D57, 2701 local, HSM, and ATC respectively. When power is supplied to the DCU, the DFM is initialized and the microprocessor begins executing programs stored in the ROM. Twelve firmware programs stored in the ROM provide all of the operating modes for the DFM.

4. The Lockheed Recorder 417 is a portable wide-band magnetic tape recorder. Completely modularized, the Model 417 WB is capable of recording up to seven tracks of either FM or direct data on 7-inch reels of ½-inch

instrumentation tape. As a part of the SADE system, the reproduce mode can be used to digitize from one to six channels of analog information. The recorder operates at three speeds: 3 3/4, 15, or 30 ips.

5. The Film Printer/Viewer display unit is used either on or off-line to display and record analog data. The option of level slicing the data before it is displayed on CRT is available. Permanent record of the video information on the display unit is made by using a variable speed 70 mm continuous strip camera.

6. The ASR-33 Teletype is used for communication between the computer and the SADE equipment at RSI. Local and line modes can be used with off-line and on-line operations, respectively. Paper tape serves as an optional input/output medium.

7. The Dicomed D15 tape unit serves as a device for the reading and writing of digital information on computer magnetic tape. An Atron controller permits communication between the tape unit and the D57 digitizer, analog tape unit, monitor, film printer, or computer.

<u>South Dakota State University Computer Center Facilities</u>

1. IBM 370/145 computer with 512K real memory
2. 6-3340 disk drives
3. 4-3420 tape drives
4. 1-1403 line printer
5. 1-2540 card reader/punch
6. 1-3704 teleprocessing unit
7. 1-2701 data adapter unit
8. 1-2821 control unit
9. 1-1627^{II} calcomp drum plotter

<u>SADE System Functions</u>

Offline:

1. Video monitor display of D57 output data
2. Video monitor display of analog tape data
3. Transmission of analog information to film printer

4. Storage of D57 data on D15 tape unit
5. Storage of analog tape data on D15 tape unit
6. Transmission of data from D15 tape unit to film printer
7. Video monitor display of D15 tape data

Online:

1. Teletype communications (including punched paper tape) to and from computer
2. Computer communication to D57
3. Transmission of D57 output data to computer
4. Transmission of a maximum of six channels of analog tape data to computer
5. Video monitor display of data from computer
6. Transmission of computer-stored data to film printer
7. Transmission of data from computer to D15 tape unit and vice versa

Figure 1 is a summary of the above SADE functions.

SADE Input and Output

Input Data:

35 mm film transparency
70 mm film transparency
9-inch film transparency
Analog tape (1 to 6 channels)
Digital tape
Punched paper tape

Output Data:

Monitor display (B/W or color)
70 mm film printer output
Digital tape
Photography from monitor
Punched paper tape
Output products from computer peripherals

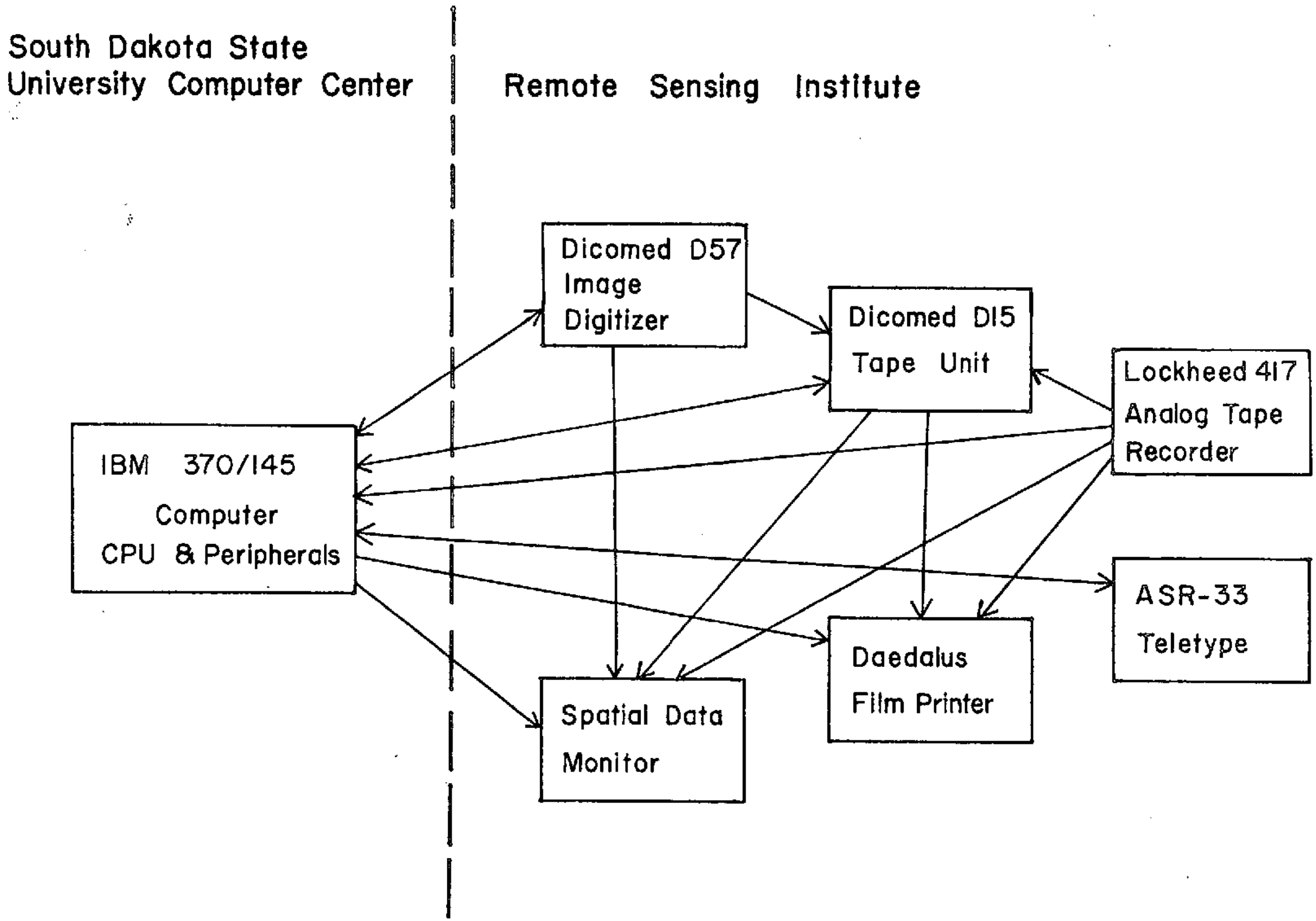


Figure 1. SADE System Communication Paths

SADE System Software

On-line control of the SADE system operation is provided by SAM (System Analysis Monitor). This Fortran program establishes communication with the computer and routes each teletype task request to the proper subroutine. A variety of Fortran and Assembler subroutines are available for performing the various on-line SADE functions and sub-device diagnostics.